Stormwater Management Report
Proposed Site Improvements
Map 55 Lot 94
88 Worcester Street
Grafton, Massachusetts

Prepared for:

Petrogas Group New England, Inc.
168 North Main Street
Andover, MA 01810

November 7, 2017

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MHF Project No. 408816

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SECTION 1 EXECUTIVE SUMMARY

This report contains a stormwater management analysis for the proposed site improvements at 88 Worcester Street in Grafton, Massachusetts. The analysis includes both pre- and post-development calculations of stormwater runoff rates at specific locations on the project site and has been prepared in accordance with both Town of Grafton requirements and the guidelines contained in the Massachusetts Department of Environmental Protection (MassDEP) Massachusetts Stormwater Handbook; Volumes 1-3.

The project site consists of a 0.698 acre +/- parcel located on the northern side of Worcester Street, across from Hitchings Road. The study watershed is an upland area which is approximately 0.75 acres in size which is bounded by Worcester Street to the south and by Axtell Brook and the associated wetlands on the remaining three sides. The watershed predominantly consists of the existing developed area on the project site which includes the existing service station, fueling canopy & dispensers, and associated paved parking areas. There are portions of undisturbed wooded buffer along the perimeter of the property. Most of the parcel sheet flows directly to the surrounding resource area, with some front portions of the site draining to the closed drainage system along Worcester Street which ultimately discharges to Axtell Brook.

Petrogas Group New England, Inc. (Petrogas) is proposing site improvements at the existing service station. The proposed improvements include converting the existing service station to a convenience store, removing the existing fuel canopy and dispenser islands, and constructing a new fuel dispensing area with 4 dispensers (8 fueling positions), and a reconfigured paved parking lot with 18 parking spaces. Site work will also include site grading, erosion control measures, utility connections and a construction of a new stormwater management system.

This project, which is considered a redevelopment project under the DEP Stormwater Policy Standards, provides significant onsite stormwater management improvements in comparison to the existing site conditions. To accommodate the stormwater runoff from the impervious surfaces on the property, a new closed drainage system consisting of deep-sump, hooded catch basins, a First Defense hydrodynamic separator (water quality) unit, and a rain garden will be constructed. The BMP's included in the proposed stormwater system are designed in accordance with Mass DEP Stormwater Policy Standards, and will improve stormwater quality and quantity to all design points.

The results of the pre- and post-development stormwater analysis at the design point are summarized as shown in the following table:

Table 1: Analysis Summary

Design Storm	Pre-Development (cfs)	Post-Development (cfs)	Change (cfs)
DESIGN POINT #1 (Axtell Brook & Wetlands)			
2-year	1.3	0.4	-0.9
10-year	2.4	1.9	-0.5
100-year	4.0	2.9	-1.1

(All values shown are peak rates in CFS)

In conclusion, by incorporating a new on-site drainage system that includes provisions for stormwater treatment, detention, and infiltration there will be a decrease in the peak rate of runoff leaving the property as a result of this project.

SECTION 2 EXISTING CONDITIONS

The project site consists of a 0.698 acre +/- parcel located on the northern side of Worcester Street, across from Hitchings Road. The parcel is an isolated upland area which is bounded by Worcester Street to the south and by Axtell Brook and the associated wetlands on the remaining three sides. Axtell Brook is classified as a perennial stream; therefore, the site is within the *200-foot Riverfront Area* as defined by MassDEP. The site predominantly consists of the existing developed area which includes the existing service station, fueling canopy & dispensers, and associated gravel & paved parking areas. There are portions of undisturbed wooded buffer along the perimeter of the property. Most of the parcel sheet flows directly to the surrounding resource area, with some front portions of the site draining to the closed drainage system along Worcester Street which ultimately discharges to Axtell Brook.

An examination of the soil map for the area as published on the NRCS Web Soil Survey website indicates that the soil in the area of the project site are identified as "Hinckley" soils which consist of loamy sand and have a hydrologic soil group classification "A."

On-site test pits were performed for purposes of identifying the seasonal high water table. The observed seasonal high water table was at a depth greater than 96". Test pit logs can be found in Appendix C of this report.

SECTION 3 PROPOSED CONDITIONS

Petrogas Group New England, Inc. (Petrogas) is proposing site improvements at the existing service station. The proposed improvements include converting the existing service station to a convenience store, removing the existing fuel canopy and dispenser islands, and constructing a new fuel dispensing area with 4 dispensers (8 fueling positions), and a reconfigured paved parking lot with 18 parking spaces. Site work will also include site grading, erosion control measures, utility connections and a construction of a new stormwater management system.

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In order to safeguard against oil or gas introduction into the drainage systems, storm water runoff from parking areas and driveways would be collected into hooded catch basins with deep sumps (see Site Plan Details). Such pretreatment of storm water reduces both suspended solids and oils in the drainage system and is recommended by DEP's Stormwater Management Handbook. Runoff would then further be treated by means of a First Defense hydrodynamic separator (water quality) unit designed to filter suspended solids/silt/debris. A total of > 44% TTS removal is achieved prior to discharge into the proposed rain garden, as required by MassDEP for LUHPPL sites.

Stormwater treatment is achieved through filtration within the rain garden filter media layer. Onsite recharge of treated stormwater below is filter media is implemented to the maximum extent practicable and achieves the required 2' of separation to the ESHWT as required by MassDEP. The rain garden is sized to provide treatment of the full water quality volume for the LUHPPL use (1" of runoff).

Another safeguard against future intrusion of contaminants into the groundwater is the implementation of an Operation & Maintenance Plan, which would assure proper function of drainage components and reduce TSS entering the system.

To prevent erosion and sedimentation during construction, Best Management Practices including stabilized construction exits, silt fence, catch basin inserts, and temporary and permanent seeding have been incorporated into the construction sequence.

The total area of disturbance related to the proposed construction on this property is approximately 30,250 square feet; therefore, the project not is subject to the US EPA Construction General Permit requirements.

Storm water Quality Controls:

1. **Street Sweeping** - to capture sediment prior to entering the drainage system. This would be done on a scheduled basis. TSS Removal Rate = 5%
2. **Hooded Catch Basins with Deep Sumps** to capture, treat and redirect storm water toward the proposed above and underground detention systems. TSS Removal Rate = 25%
3. **First Defense units** – to provide adequate pretreatment and TSS removal of stormwater runoff from a LUHPPL prior to discharge to the infiltration basin. TSS removal rate = 50%.
4. **Rain Garden** – to treat, recharge, detain and control stormwater flows prior to discharge to design points. TSS removal rate = 90%

Groundwater Recharge:

In order to provide groundwater recharge to the maximum extent practicable, the site plans have incorporated a rain garden which is designed to recharge treated stormwater below the filter media layer. Calculations supporting the rates and capacities are included below.

Stormwater Quantity Controls:

The **rain garden** is designed such that it controls discharges via a stone overflow weir for the 2, 10 & 100-year events.

The overall system thereby achieves the following:

- Control of runoff rates to abutting properties.
- Water quality maintenance – TSS removal from storm water of more than 80%.

The point of analysis is Axtell Brook & the associated wetlands.

Stormwater Management & Water Quality Calculations:

Standard # 1: Untreated Stormwater

- Full Compliance

No new storm water conveyances are to discharge untreated storm water directly to or cause erosion in wetlands or waters of the Commonwealth.

Standard # 2: Post Development Peak Discharge Rates

- Full Compliance

The storm water management system is designed so that post-development peak discharge rates do not exceed pre-development peak discharge rates.

Standard # 3: Groundwater Recharge

- Compliance to the maximum extent practicable. The volume is provided but does not receive runoff from > 60% of the onsite impervious areas.

Proposed recharge systems: Underground Stormtech arch chamber & stone infiltration system.

In accordance with Massachusetts stormwater policy, **A** soils require a volume to recharge of **0.6 inches of runoff**.

Total Proposed onsite impervious area = 16,069 sf

Volume required to be recharged:

A-soils = 0.6 inches x 1ft/ 12" x 16,069 sf = **803 c.f.**

Total Site Volume required to be recharged = <u>803 c.f.</u>

Site Volume recharge provided = Volume within the rain garden below the outlet weir elevation (measured statically).

Total Volume Provided = **<u>1,241 c.f.</u>** (See attached Hydrocad Stage-Storage tables)

= **1,241 c.f.** Total Volume Recharged >803 c.f. (√ ok)

Standard # 4: TSS Removal

- Full Compliance

Explanation of systems:

Parking and driveway areas would be treated by hooded Catch Basins with deep sumps prior to discharge into a First Defense hydrodynamic separator (water quality) unit. As required, >44% TSS removal is achieved prior to discharge into the rain garden (for LUHPPL areas). The rain garden provides 90% TSS removal after adequate pre-treatment.

Canopy and C-Store runoff would be routed through the First Defense Unit and the rain garden.

Calculations: Water Quality Volume

Roof & Canopy Runoff (Non-LUHPPL):

WQV = 0.5" x Impervious Area

= 0.5" x 1ft/ 12" x 4,083 sf = **170 c.f.**

Onsite Pavement Runoff (LUHPPL):

WQV = 1.0" x Impervious Area

= 1.0" x 1ft/ 12" x 11,986 sf = **999 c.f.**

Total Site WQV Required =1,169 c.f.

Treatment Volume Provided within Rain Garden = **1,241 c.f.** > 1,169 c.f. (√ ok)

Calculations: TSS Removal

Drainage Area	BMP	TSS Removal Rate
Driveway/Parking	**Street Sweeping**	**5%**
Driveway/Parking	**Catch Basin w/sump**	**25%**
Driveway/Parking/Roofs	**First Defense**	**50%**
Driveway/Parking/Roofs	**Rain Garden**	**25%**

C-Store roof & canopy runoff:

Beginning Load: 1.00 x First Defense removal rate (0.50) = **0.50**

Load Remaining = 1.00 – 0.50 = 0.50

Remaining Load: 0.50 x Rain Garden removal rate (0.90) = **0.45**

Load Remaining = 0.50 – 0.45 = 0.05

TSS Removal Rate = (1.00 – 0.05) **= 95%**

Runoff from paved surfaces:

Beginning Load: 1.00 x Street Sweeping removal rate (0.05) = **0.05**

Load Remaining = 1.00 – 0.05 = 0.95

Remaining Load: 0.95 x Catch Basin w/ sump removal rate (0.25) = **0.24**

Load Remaining = 0.95 – 0.24 = 0.71

Remaining Load: 0.71 x First Defense removal rate (0.50) = **0.35**

Load Remaining = 0.71 – 0.35 = 0.36

Remaining Load: 0.36 x Rain Garden removal rate (0.90) = **0.32**

Load Remaining = 0.36 – 0.32 = 0.03

TSS Removal Rate = (1.00 – 0.03) **= 97%**

Standard # 5: Higher potential pollutant loads

The site does contain land uses with higher potential pollutant loads as it is a gas station development.

Standard # 6: Protection of critical areas

The site does not contain critical areas with sensitive resources.

Standard # 7: Redevelopment projects

The site is a redevelopment project.

Standard # 8: Erosion/sediment control

Erosion and sediment controls are incorporated into the project design to prevent erosion.

Standard #9: Operation/maintenance plan

A long term operation and maintenance plan meeting the requirements of this standard has been prepared and is included as a separate document.

Standard #10: (Illicit Discharges)

To the best of our knowledge, the site does not contain any illicit discharges. See attached illicit discharge statement.

SECTION 4 STORMWATER MODELING METHODOLOGY

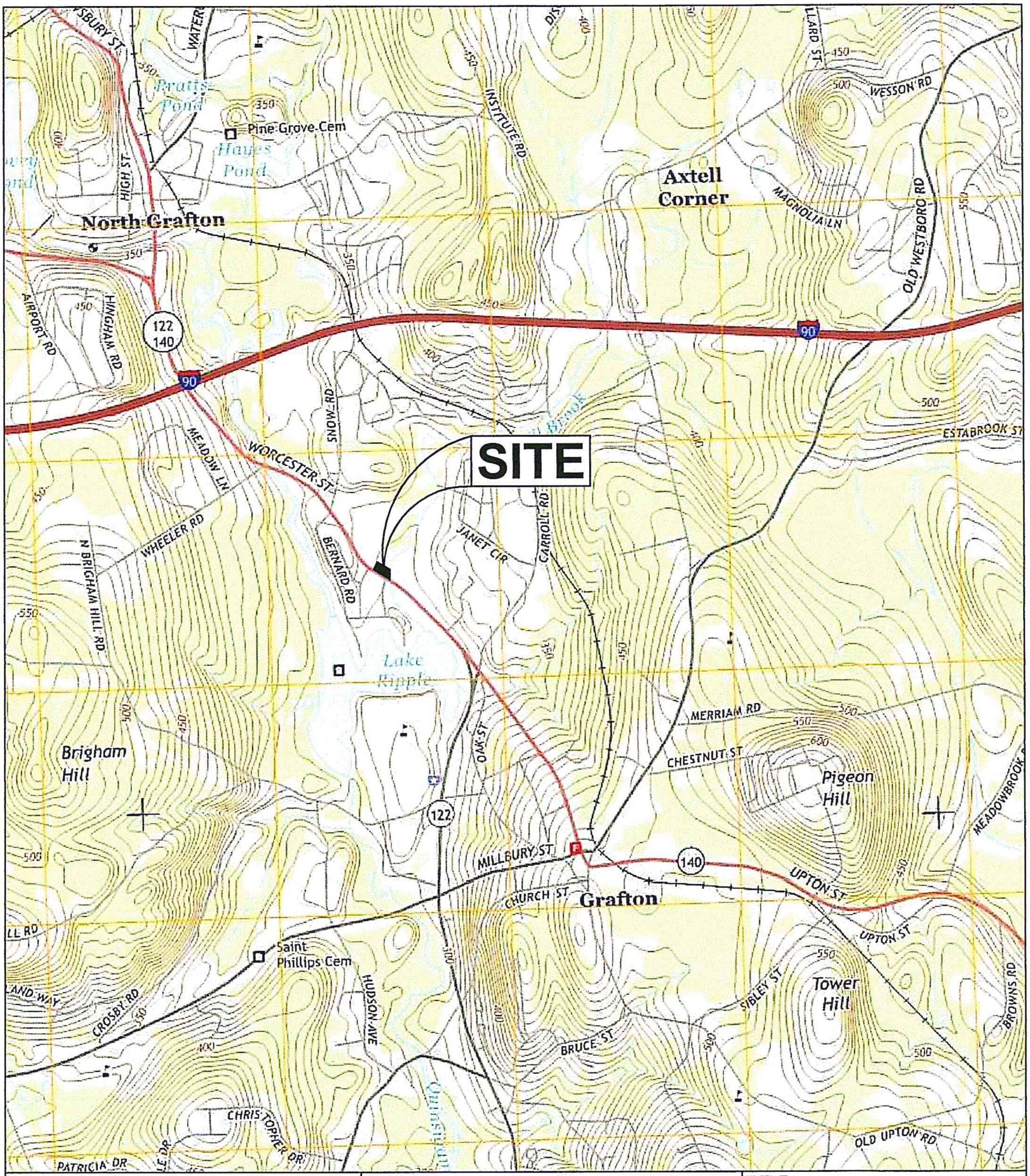
The drainage system for this project was modeled using HydroCAD, a stormwater modeling computer program that analyzes the hydrology, and hydraulics of stormwater runoff. HydroCAD is based largely on the hydrology techniques developed by the Soil Conservation Service (SCS/NRCS), combined with other hydrology and hydraulics calculations. For a given rainfall event, these techniques are used to generate hydrographs throughout a watershed. This provides verification that a given drainage system is adequate for the area under consideration, or to predict where flooding or erosion is likely to occur.

In HydroCAD, each watershed is modeled as a Subcatchment, streams and culverts as a Reach (or Pond, depending on available storage capacity), and large wetlands and other natural or artificial storage areas as a Pond. SCS hydrograph generation and routing procedures were used to model both Pre-development and Post-development runoff conditions.

The Pre-development and Post-development watershed limits and the subcatchment characteristics were determined using both USGS and on-the-ground topographic survey information and through visual, on-site inspection. Conservative estimates were used at all times in estimating the hydrologic characteristics of each watershed or subcatchment.

APPENDIX A

USGS Map



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88 Worcester Street
Grafton, Massachusetts
Map 55 Lot 94

PREPARED FOR:
Petrogas Group New England, Inc.
168 North Main Street
Andover, MA 01810

TITLE:
USGS SITE LOCATION MAP
GRAFTON MA
QUADRANGLE

DATE: November 7, 2017

PROJ. NO.
408816

SCALE:
1"=2,000'

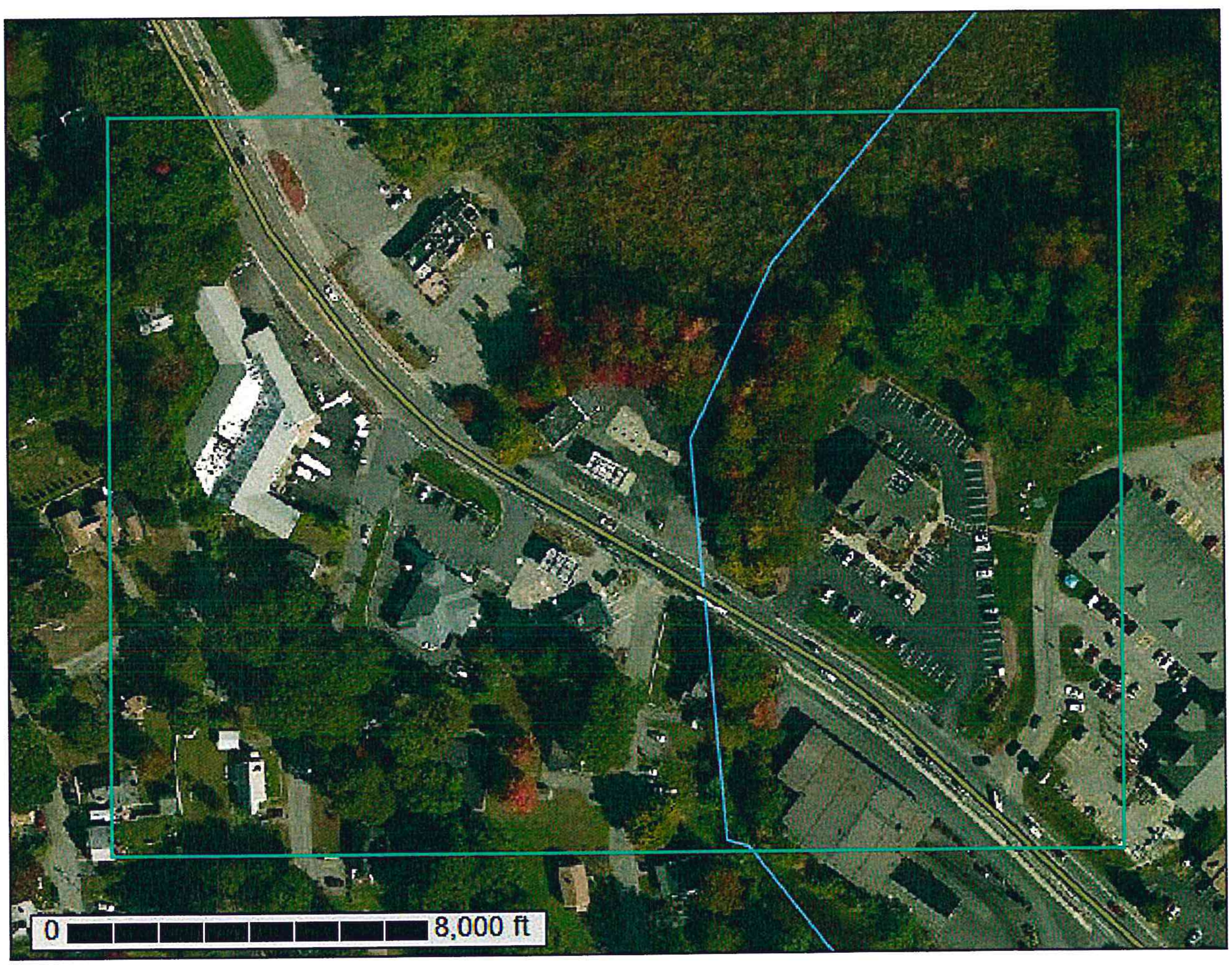
APPENDIX B

NRCS Soil Information

USDA
United States Department of Agriculture
NRCS
Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for Worcester County, Massachusetts, Southern Part



October 24, 2017

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

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Contents

How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

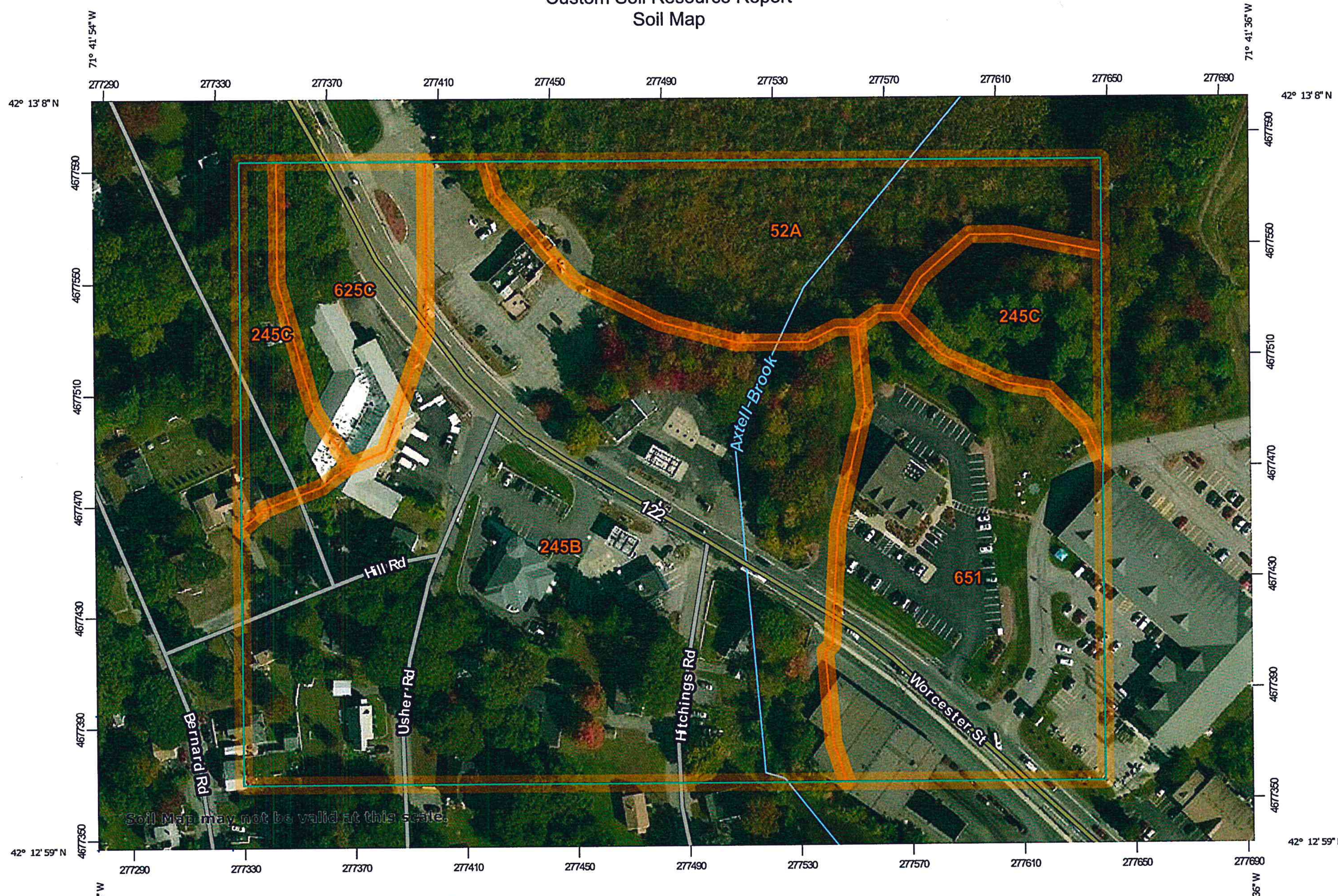
Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Custom Soil Resource Report
Soil Map



Map Scale: 1:1,900 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 25, 50, 100, 150

Feet: 0, 50, 100, 200, 300

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 19N WGS84

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:25,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Worcester County, Massachusetts, Southern Part
Survey Area Data: Version 9, Sep 15, 2016

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Sep 12, 2014—Sep 28, 2014

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background

MAP LEGEND

MAP INFORMATION

imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
52A	Freetown muck, 0 to 1 percent slopes	2.5	14.5%
245B	Hinckley loamy sand, 3 to 8 percent slopes	8.6	50.0%
245C	Hinckley loamy sand, 8 to 15 percent slopes	1.5	8.6%
625C	Hinckley-Urban land complex, 0 to 15 percent slopes	1.2	6.8%
651	Udorthents, smoothed	3.5	20.2%
Totals for Area of Interest		**17.2**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Worcester County, Massachusetts, Southern Part

52A—Freetown muck, 0 to 1 percent slopes

Map Unit Setting

National map unit symbol: 2t2q9
Elevation: 0 to 1,110 feet
Mean annual precipitation: 36 to 71 inches
Mean annual air temperature: 39 to 55 degrees F
Frost-free period: 140 to 240 days
Farmland classification: Farmland of unique importance

Map Unit Composition

Freetown and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Freetown

Setting

Landform: Bogs, depressions, depressions, kettles, marshes, swamps
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Tread, dip
Down-slope shape: Concave
Across-slope shape: Concave
Parent material: Highly decomposed organic material

Typical profile

Oe - 0 to 2 inches: mucky peat
Oa - 2 to 79 inches: muck

Properties and qualities

Slope: 0 to 1 percent
Percent of area covered with surface fragments: 0.0 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Very poorly drained
Runoff class: Negligible
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to high (0.14 to 14.17 in/hr)
Depth to water table: About 0 to 6 inches
Frequency of flooding: Rare
Frequency of ponding: Frequent
Available water storage in profile: Very high (about 19.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 5w
Hydrologic Soil Group: B/D
Hydric soil rating: Yes

Minor Components

Whitman

Percent of map unit: 5 percent
Landform: Depressions, drainageways
Landform position (two-dimensional): Toeslope

Landform position (three-dimensional): Base slope
Down-slope shape: Concave
Across-slope shape: Concave
Hydric soil rating: Yes

Scarboro

Percent of map unit: 5 percent
Landform: Depressions, drainageways
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Base slope, tread, dip
Down-slope shape: Concave
Across-slope shape: Concave
Hydric soil rating: Yes

Swansea

Percent of map unit: 5 percent
Landform: Bogs, depressions, depressions, kettles, marshes, swamps
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Tread, dip
Down-slope shape: Concave
Across-slope shape: Concave
Hydric soil rating: Yes

245B—Hinckley loamy sand, 3 to 8 percent slopes

Map Unit Setting

National map unit symbol: 2svm8
Elevation: 0 to 1,430 feet
Mean annual precipitation: 36 to 53 inches
Mean annual air temperature: 39 to 55 degrees F
Frost-free period: 140 to 250 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Hinckley and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Hinckley

Setting

Landform: Eskers, kames, kame terraces, outwash plains, outwash terraces, moraines, outwash deltas
Landform position (two-dimensional): Summit, shoulder, backslope, footslope
Landform position (three-dimensional): Nose slope, side slope, base slope, crest, tread, riser
Down-slope shape: Linear, convex, concave
Across-slope shape: Convex, linear, concave
Parent material: Sandy and gravelly glaciofluvial deposits derived from gneiss and/or granite and/or schist

Typical profile

Oe - 0 to 1 inches: moderately decomposed plant material
A - 1 to 8 inches: loamy sand
Bw1 - 8 to 11 inches: gravelly loamy sand
Bw2 - 11 to 16 inches: gravelly loamy sand
BC - 16 to 19 inches: very gravelly loamy sand
C - 19 to 65 inches: very gravelly sand

Properties and qualities

Slope: 3 to 8 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Excessively drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to very high (1.42 to 99.90 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Very low (about 3.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3s
Hydrologic Soil Group: A
Hydric soil rating: No

Minor Components

Windsor

Percent of map unit: 8 percent
Landform: Eskers, kames, kame terraces, outwash plains, outwash terraces, moraines, outwash deltas
Landform position (two-dimensional): Summit, shoulder, backslope, footslope
Landform position (three-dimensional): Nose slope, side slope, base slope, crest, tread, riser
Down-slope shape: Linear, convex, concave
Across-slope shape: Convex, linear, concave
Hydric soil rating: No

Sudbury

Percent of map unit: 5 percent
Landform: Kame terraces, outwash plains, outwash terraces, moraines, outwash deltas
Landform position (two-dimensional): Backslope, footslope
Landform position (three-dimensional): Side slope, base slope, head slope, tread
Down-slope shape: Concave, linear
Across-slope shape: Linear, concave
Hydric soil rating: No

Agawam

Percent of map unit: 2 percent
Landform: Eskers, kames, kame terraces, outwash plains, outwash terraces, moraines, outwash deltas
Landform position (two-dimensional): Summit, shoulder, backslope, footslope

Landform position (three-dimensional): Nose slope, side slope, base slope, crest, tread, riser
Down-slope shape: Linear, convex, concave
Across-slope shape: Convex, linear, concave
Hydric soil rating: No

245C—Hinckley loamy sand, 8 to 15 percent slopes

Map Unit Setting

National map unit symbol: 2svm9
Elevation: 0 to 1,480 feet
Mean annual precipitation: 36 to 71 inches
Mean annual air temperature: 39 to 55 degrees F
Frost-free period: 140 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Hinckley and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Hinckley

Setting

Landform: Eskers, kames, kame terraces, outwash plains, outwash terraces, moraines, outwash deltas
Landform position (two-dimensional): Shoulder, toeslope, footslope, backslope
Landform position (three-dimensional): Crest, head slope, nose slope, side slope, riser
Down-slope shape: Convex, concave, linear
Across-slope shape: Concave, linear, convex
Parent material: Sandy and gravelly glaciofluvial deposits derived from gneiss and/or granite and/or schist

Typical profile

Oe - 0 to 1 inches: moderately decomposed plant material
A - 1 to 8 inches: loamy sand
Bw1 - 8 to 11 inches: gravelly loamy sand
Bw2 - 11 to 16 inches: gravelly loamy sand
BC - 16 to 19 inches: very gravelly loamy sand
C - 19 to 65 inches: very gravelly sand

Properties and qualities

Slope: 8 to 15 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Excessively drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to very high (1.42 to 99.90 in/hr)
Depth to water table: More than 80 inches

Frequency of flooding: None
Frequency of ponding: None
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Low (about 3.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4e
Hydrologic Soil Group: A
Hydric soil rating: No

Minor Components

Windsor

Percent of map unit: 5 percent
Landform: Eskers, kames, kame terraces, outwash plains, outwash terraces, moraines, outwash deltas
Landform position (two-dimensional): Shoulder, backslope, footslope, toeslope
Landform position (three-dimensional): Nose slope, side slope, crest, head slope, riser
Down-slope shape: Convex, concave, linear
Across-slope shape: Concave, linear, convex
Hydric soil rating: No

Sudbury

Percent of map unit: 5 percent
Landform: Kame terraces, outwash plains, outwash terraces, moraines, outwash deltas
Landform position (two-dimensional): Backslope, footslope
Landform position (three-dimensional): Base slope, tread
Down-slope shape: Concave, linear
Across-slope shape: Linear, concave
Hydric soil rating: No

Merrimac

Percent of map unit: 5 percent
Landform: Eskers, kames, outwash plains, outwash terraces, moraines
Landform position (two-dimensional): Shoulder, backslope, footslope, toeslope
Landform position (three-dimensional): Side slope, head slope, nose slope, crest, riser
Down-slope shape: Convex
Across-slope shape: Convex
Hydric soil rating: No

625C—Hinckley-Urban land complex, 0 to 15 percent slopes

Map Unit Setting

National map unit symbol: 2svm1
Elevation: 140 to 770 feet
Mean annual precipitation: 36 to 71 inches

Mean annual air temperature: 39 to 55 degrees F
Frost-free period: 140 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition
Hinckley and similar soils: 45 percent
Urban land: 35 percent
Minor components: 20 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Hinckley

Setting
Landform: Eskers, kames, kame terraces, outwash plains, outwash terraces, moraines, outwash deltas
Landform position (two-dimensional): Footslope, toeslope, summit, shoulder, backslope
Landform position (three-dimensional): Nose slope, side slope, crest, head slope, riser, tread
Down-slope shape: Linear, convex, concave
Across-slope shape: Linear, concave, convex
Parent material: Sandy and gravelly glaciofluvial deposits derived from gneiss and/or granite and/or schist

Typical profile
A - 0 to 8 inches: loamy sand
Bw1 - 8 to 11 inches: gravelly loamy sand
Bw2 - 11 to 16 inches: gravelly loamy sand
BC - 16 to 19 inches: very gravelly loamy sand
C - 19 to 65 inches: very gravelly sand

Properties and qualities
Slope: 0 to 15 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Excessively drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to very high (1.42 to 99.90 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Very low (about 2.9 inches)

Interpretive groups
Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4e
Hydrologic Soil Group: A
Hydric soil rating: No

Description of Urban Land

Typical profile
M - 0 to 6 inches: cemented material

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8
Hydrologic Soil Group: D
Hydric soil rating: Unranked

Minor Components

Udorthents

Percent of map unit: 10 percent
Hydric soil rating: No

Windsor

Percent of map unit: 5 percent
Landform: Eskers, kames, kame terraces, outwash plains, outwash terraces, moraines, outwash deltas
Landform position (two-dimensional): Footslope, shoulder, toeslope, backslope, summit
Landform position (three-dimensional): Head slope, nose slope, side slope, crest, riser, tread
Down-slope shape: Concave, convex, linear
Across-slope shape: Linear, concave, convex
Hydric soil rating: No

Merrimac

Percent of map unit: 5 percent
Landform: Eskers, kames, kame terraces, outwash plains, outwash terraces, moraines
Landform position (two-dimensional): Shoulder, toeslope, summit, backslope, footslope
Landform position (three-dimensional): Side slope, nose slope, head slope, crest, riser, tread
Down-slope shape: Linear, convex, concave
Across-slope shape: Concave, linear, convex
Hydric soil rating: No

651—Udorthents, smoothed

Map Unit Setting

National map unit symbol: 9bfc
Elevation: 0 to 3,000 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 145 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Udorthents and similar soils: 80 percent
Urban land: 20 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Udorthents

Setting

Parent material: Made land over firm coarse-loamy basal till and/or dense coarse-loamy lodgment till

Typical profile

H1 - 0 to 6 inches: variable
H2 - 6 to 60 inches: variable

Properties and qualities

Slope: 0 to 25 percent
Depth to restrictive feature: More than 80 inches
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to very high (0.06 to 20.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6s
Hydrologic Soil Group: A
Hydric soil rating: No

Soil Information for All Uses

Soil Properties and Qualities

The Soil Properties and Qualities section includes various soil properties and qualities displayed as thematic maps with a summary table for the soil map units in the selected area of interest. A single value or rating for each map unit is generated by aggregating the interpretive ratings of individual map unit components. This aggregation process is defined for each property or quality.

Soil Qualities and Features

Soil qualities are behavior and performance attributes that are not directly measured, but are inferred from observations of dynamic conditions and from soil properties. Example soil qualities include natural drainage, and frost action. Soil features are attributes that are not directly part of the soil. Example soil features include slope and depth to restrictive layer. These features can greatly impact the use and management of the soil.

Hydrologic Soil Group

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

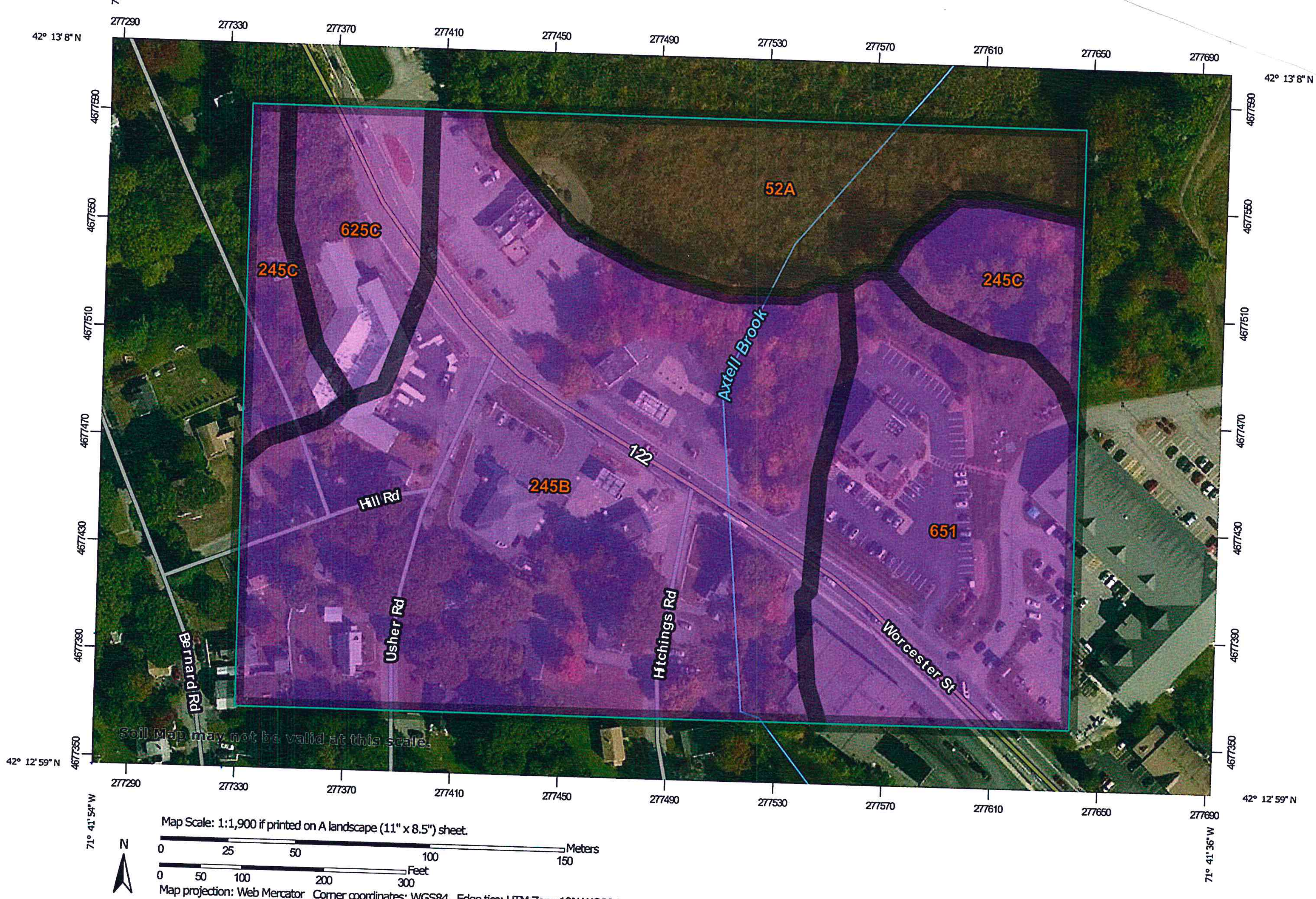
Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.


71° 41' 54" W
42° 13' 8" N
277290
277330
277370
277410
277450
277490
277530
277570
277610
277650
277690
4677590
4677550
4677510
4677470
4677430
4677390
4677350
52A
625C
245C
245C
245B
651
Axtell Brook
122
Hill Rd
Usher Rd
Hitchings Rd
Worcester St
Bernard Rd
Soil Map may not be valid at this scale.
42° 12' 59" N
71° 41' 36" W
N
Map Scale: 1:1,900 if printed on A landscape (11" x 8.5") sheet.
0 25 50 100 150 Meters
0 50 100 200 300 Feet
Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 19N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features

Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:25,000.

> Warning: Soil Map may not be valid at this scale.
>
> Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Worcester County, Massachusetts, Southern Part
Survey Area Data: Version 9, Sep 15, 2016

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Sep 12, 2014—Sep 28, 2014

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background

MAP LEGEND	MAP INFORMATION
	imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Table—Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
52A	Freetown muck, 0 to 1 percent slopes	B/D	2.5	14.5%
245B	Hinckley loamy sand, 3 to 8 percent slopes	A	8.6	50.0%
245C	Hinckley loamy sand, 8 to 15 percent slopes	A	1.5	8.6%
625C	Hinckley-Urban land complex, 0 to 15 percent slopes	A	1.2	6.8%
651	Udorthents, smoothed	A	3.5	20.2%
Totals for Area of Interest			**17.2**	**100.0%**

Rating Options—Hydrologic Soil Group

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

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APPENDIX C

Test Pit Logs

FORM 11 - SOIL EVALUATOR FORM

Location Address or Lot No. 88 Worcester Street, Grafton, MA

On-site Review

Deep Hole Number: TP-1 Date: 8/10/17 Time: AM Weather: Sunny 80s

Location (identify on site plan)

Land Use Commercial Slope (%) 0-5% Surface Stones None

Vegetation Landscaping

Landform

Position on landscape (sketch on back)

Distances from:

Open Water Body >25 feet Drainage way >5 feet

Possible Wet Area >25 feet Property Line >10 feet

Drinking Water Well >100 feet Other

DEEP OBSERVATION HOLE LOG*

Depth from Surface (Inches)	Soil Horizon	Soil Texture (USDA)	Soil Color (Munsell)	Soil Mottling	Other (Structure, Stones, Boulders, Consistency, % Gravel)
0-60"	Fill	Mixed Soils/Urban Fill			
60-120"	C	Sand	2.5y 5/3		

* MINIMUM OF 2 HOLES REQUIRED AT EVERY PROPOSED DISPOSAL AREA

Parent Material (geologic): Till Depth to Bedrock: >120"

Depth to Groundwater: 96" Standing Water in Hole: 96" Weeping from pit face: 96"

Estimated Seasonal High Groundwater: 96"

FORM 11 - SOIL EVALUATOR FORM

Location Address or Lot No. 88 Worcester Street, Grafton, MA

On-site Review

Deep Hole Number: TP-2 Date: 8/10/17 Time: AM Weather: Sunny 80s

Location (identify on site plan)

Land Use Commercial Slope (%) 0-5% Surface Stones None

Vegetation Landscaping

Landform

Position on landscape (sketch on back)

Distances from:

Open Water Body >25 feet Drainage way >5 feet

Possible Wet Area >25 feet Property Line >10 feet

Drinking Water Well >100 feet Other

DEEP OBSERVATION HOLE LOG*

Depth from Surface (Inches)	Soil Horizon	Soil Texture (USDA)	Soil Color (Munsell)	Soil Mottling	Other (Structure, Stones, Boulders, Consistency, % Gravel)
0-65"	Fill	Mixed Soils/Urban Fill			
65-120"	C	Sand	2.5y 5/3		

* MINIMUM OF 2 HOLES REQUIRED AT EVERY PROPOSED DISPOSAL AREA

Parent Material (geologic): Till Depth to Bedrock: >120"

Depth to Groundwater: 96" Standing Water in Hole: 96" Weeping from pit face: 96"

Estimated Seasonal High Groundwater: 96"

APPENDIX D

Miscellaneous Calculations

OUTLET APRON DESIGN

MHF Design Consultants, Inc.
ENGINEERS • PLANNERS • SURVEYORS

Project: Petrogas - Grafton, MA   Job # 408816
Date: 7-Nov-17

FES#1 OUTLET APRON
(from HydroCAD **POND DMH2)**

Q10= 1.92 cfs
D_o = 15 inches
Tw = 2.96 feet

Design Criteria
Apron Dimensions

The dimensions of the apron at the outlet of the pipe shall be determined as follows:

1.) The width of the apron at the outlet of the pipe or channel shall be 3 times the diameter of the pipe or width of the channel.

USE THIS W= **3.75** feet

2.) The length of the apron shall be determined from the following formula when the tailwater depth at the outlet of the pipe or channel is less than one-half the diameter of the pipe or one-half the width of the channel.

La=1.8*Q/ Do^3/2+ 7Do
La= **11.22** feet

Where: La is the length of the apron
Q is the discharge from the pipe or channel
D_o is the diameter of pipe of width of channel

3.) The length of the apron shall be determined from the following formula when the tailwater depth at the outlet of the pipe or channel is greater than one-half the diameter of the pipe or one-half the width of the channel.

USE THIS La=3.0*Qo/ Do^1.5 +7D_o
La= **12.87** feet

4.) Where there is no well defined channel downstream of the outlet the width of the downstream end of the apron shall be determined as follows:

a. For minimum tailwater conditions where the tailwater depth is less than one-half the pipe diameter:

W=3*Do+La
W= **14.97** feet

b. For maximum tailwater conditions where the tailwater depth is greater than one-half the diameter of the pipe:

USE THIS W=3*Do+0.4*La
W= **8.90** feet

5.) Where there is a stable well-defined channel downstream of the apron, the bottom of the apron shall be equal to the width of the channel.

W= **8** feet

6.) The side of the apron in a well-defined channel shall be 2:1 (horizontal to vertical) or flatter. The height of the structural lining along the channel sides shall begin at the elevation equal to the top of conduit and taper down to the channel bottom through the length of the apron.

7.) The bottom grade of the apron shall be level (0% grade). No overfall is allowable at the end of the apron.

8.) The apron shall be located so that there are no bends in the horizontal alignment of the apron

Rock Riprap

The following criteria shall be used to determine the dimensions of the rock riprap used for the apron:

1.) The median stone diameter shall be determined using the formula:

d_{50}=0.02*Q^4/3/(Tw*D_o)

d_{50}= **0.15** inches **USE** 3 inches

d_{50} minimum 3 inches

Where: d_{50} is the median stone diameter in feet
Tw is the tailwater depth above the invert of the pipe channel in feet
Q is the discharge from the pipe or channel in cubic feet per second
D_o is the diameter of the pipe or width of the channel in feet

2.) Fifty percent by weight of the riprap mixture shall be smaller the than median stone size designated as d_{50}. The largest stone size in the mixtureshall be 1.5 times the d_{50} size.

3.) The quality and gradation of the rock, the thickness of the riprap lining, filter material and the quality of the stone shall meet the requirements in the Rock Riprap BMP. The minimum depth shall be 6 inches or 1.5 times the largest stone size in the mixture whichever is larger (d).

Thickness of the riprap
d = 1.5*(1.5*d_{50}(largest stone size))
d= 7 inches*

* must use a minimum of 6"

Rock Rip Rap Gradation

% of weight smaller than the given size	size of stone in inches		
100	**4.5**	to	**6.0**
85	**3.9**	to	**5.4**
50	**3.0**	to	**4.5**
15	**0.9**	to	**1.5**

Drawdown within 72 hours Analysis for Static Method

Proposed Above Ground Infiltration System

Infiltration Rate:	2.41	inches/hour (From table 2.3.3: Rawls, Brakensiek, Saxton, 1982)
Design Infiltration Rate:	2.41	inches/hour
Volume Provide for Infiltration:	1,241	cf
Basin bottom area:	909	sf

$Time_{drawdown}$ = (Required Recharge Volume in cubic feet as determined by the Static Method)(1/Design Infiltration Rate in inches per hour)(conversion for inches to feet)(1/bottom area in feet)

$Time_{drawdown}$ = (1,241 cf) (1 / 2.41 in/hr) (1ft/12 in.) (1 / 909 sf)

= 6.80 hours

APPENDIX E

MassDEP Stormwater Checklist

Checklist for Stormwater Report

A. Introduction

Important: When filling out forms on the computer, use only the tab key to move your cursor - do not use the return key.

A Stormwater Report must be submitted with the Notice of Intent permit application to document compliance with the Stormwater Management Standards. The following checklist is NOT a substitute for the Stormwater Report (which should provide more substantive and detailed information) but is offered here as a tool to help the applicant organize their Stormwater Management documentation for their Report and for the reviewer to assess this information in a consistent format. As noted in the Checklist, the Stormwater Report must contain the engineering computations and supporting information set forth in Volume 3 of the Massachusetts Stormwater Handbook. The Stormwater Report must be prepared and certified by a Registered Professional Engineer (RPE) licensed in the Commonwealth.

The Stormwater Report must include:

- The Stormwater Checklist completed and stamped by a Registered Professional Engineer (see page 2) that certifies that the Stormwater Report contains all required submittals.[1] This Checklist is to be used as the cover for the completed Stormwater Report.
- Applicant/Project Name
- Project Address
- Name of Firm and Registered Professional Engineer that prepared the Report
- Long-Term Pollution Prevention Plan required by Standards 4-6
- Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan required by Standard 8[2]
- Operation and Maintenance Plan required by Standard 9

In addition to all plans and supporting information, the Stormwater Report must include a brief narrative describing stormwater management practices, including environmentally sensitive site design and LID techniques, along with a diagram depicting runoff through the proposed BMP treatment train. Plans are required to show existing and proposed conditions, identify all wetland resource areas, NRCS soil types, critical areas, Land Uses with Higher Potential Pollutant Loads (LUHPPL), and any areas on the site where infiltration rate is greater than 2.4 inches per hour. The Plans shall identify the drainage areas for both existing and proposed conditions at a scale that enables verification of supporting calculations.

As noted in the Checklist, the Stormwater Management Report shall document compliance with each of the Stormwater Management Standards as provided in the Massachusetts Stormwater Handbook. The soils evaluation and calculations shall be done using the methodologies set forth in Volume 3 of the Massachusetts Stormwater Handbook.

To ensure that the Stormwater Report is complete, applicants are required to fill in the Stormwater Report Checklist by checking the box to indicate that the specified information has been included in the Stormwater Report. If any of the information specified in the checklist has not been submitted, the applicant must provide an explanation. The completed Stormwater Report Checklist and Certification must be submitted with the Stormwater Report.

---

[1] The Stormwater Report may also include the Illicit Discharge Compliance Statement required by Standard 10. If not included in the Stormwater Report, the Illicit Discharge Compliance Statement must be submitted prior to the discharge of stormwater runoff to the post-construction best management practices.

[2] For some complex projects, it may not be possible to include the Construction Period Erosion and Sedimentation Control Plan in the Stormwater Report. In that event, the issuing authority has the discretion to issue an Order of Conditions that approves the project and includes a condition requiring the proponent to submit the Construction Period Erosion and Sedimentation Control Plan before commencing any land disturbance activity on the site.

Checklist for Stormwater Report

B. Stormwater Checklist and Certification

The following checklist is intended to serve as a guide for applicants as to the elements that ordinarily need to be addressed in a complete Stormwater Report. The checklist is also intended to provide conservation commissions and other reviewing authorities with a summary of the components necessary for a comprehensive Stormwater Report that addresses the ten Stormwater Standards.

Note: Because stormwater requirements vary from project to project, it is possible that a complete Stormwater Report may not include information on some of the subjects specified in the Checklist. If it is determined that a specific item does not apply to the project under review, please note that the item is not applicable (N.A.) and provide the reasons for that determination.

A complete checklist must include the Certification set forth below signed by the Registered Professional Engineer who prepared the Stormwater Report.

Registered Professional Engineer's Certification

I have reviewed the Stormwater Report, including the soil evaluation, computations, Long-term Pollution Prevention Plan, the Construction Period Erosion and Sedimentation Control Plan (if included), the Long-term Post-Construction Operation and Maintenance Plan, the Illicit Discharge Compliance Statement (if included) and the plans showing the stormwater management system, and have determined that they have been prepared in accordance with the requirements of the Stormwater Management Standards as further elaborated by the Massachusetts Stormwater Handbook. I have also determined that the information presented in the Stormwater Checklist is accurate and that the information presented in the Stormwater Report accurately reflects conditions at the site as of the date of this permit application.

Registered Professional Engineer Block and Signature

COMMONWEALTH OF MASSACHUSETTS
DAVID R. JORDAN
CIVIL
No. 34732
REGISTERED PROFESSIONAL ENGINEER

11/7/17

Signature and Date

Checklist

Project Type: Is the application for new development, redevelopment, or a mix of new and redevelopment?

☐ New development

☒ Redevelopment

☐ Mix of New Development and Redevelopment

Checklist (continued)

LID Measures: Stormwater Standards require LID measures to be considered. Document what environmentally sensitive design and LID Techniques were considered during the planning and design of the project:

- ☒ No disturbance to any Wetland Resource Areas
- ☐ Site Design Practices (e.g. clustered development, reduced frontage setbacks)
- ☒ Reduced Impervious Area (Redevelopment Only)
- ☒ Minimizing disturbance to existing trees and shrubs
- ☐ LID Site Design Credit Requested:
  - ☐ Credit 1
  - ☐ Credit 2
  - ☐ Credit 3
- ☐ Use of "country drainage" versus curb and gutter conveyance and pipe
- ☒ Bioretention Cells (includes Rain Gardens)
- ☐ Constructed Stormwater Wetlands (includes Gravel Wetlands designs)
- ☐ Treebox Filter
- ☐ Water Quality Swale
- ☐ Grass Channel
- ☐ Green Roof
- ☐ Other (describe): ____________________

Standard 1: No New Untreated Discharges

- ☒ No new untreated discharges
- ☒ Outlets have been designed so there is no erosion or scour to wetlands and waters of the Commonwealth
- ☒ Supporting calculations specified in Volume 3 of the Massachusetts Stormwater Handbook included.

Checklist (continued)

Standard 2: Peak Rate Attenuation

☐ Standard 2 waiver requested because the project is located in land subject to coastal storm flowage and stormwater discharge is to a wetland subject to coastal flooding.

☐ Evaluation provided to determine whether off-site flooding increases during the 100-year 24-hour storm.

☒ Calculations provided to show that post-development peak discharge rates do not exceed pre-development rates for the 2-year and 10-year 24-hour storms. If evaluation shows that off-site flooding increases during the 100-year 24-hour storm, calculations are also provided to show that post-development peak discharge rates do not exceed pre-development rates for the 100-year 24-hour storm.

Standard 3: Recharge

☒ Soil Analysis provided. **(See Soils Logs)**

☒ Required Recharge Volume calculation provided.

☐ Required Recharge volume reduced through use of the LID site Design Credits.

☒ Sizing the infiltration, BMPs is based on the following method: Check the method used.

☒ Static ☐ Simple Dynamic ☐ Dynamic Field[1]

☒ Runoff from all impervious areas at the site discharging to the infiltration BMP.

☐ Runoff from all impervious areas at the site is *not* discharging to the infiltration BMP and calculations are provided showing that the drainage area contributing runoff to the infiltration BMPs is sufficient to generate the required recharge volume.

☒ Recharge BMPs have been sized to infiltrate the Required Recharge Volume.

☐ Recharge BMPs have been sized to infiltrate the Required Recharge Volume *only* to the maximum extent practicable for the following reason:

- ☐ Site is comprised solely of C and D soils and/or bedrock at the land surface
- ☐ M.G.L. c. 21E sites pursuant to 310 CMR 40.0000
- ☐ Solid Waste Landfill pursuant to 310 CMR 19.000
- ☐ Project is otherwise subject to Stormwater Management Standards only to the maximum extent practicable.

☒ Calculations showing that the infiltration BMPs will drain in 72 hours are provided.

☐ Property includes a M.G.L. c. 21E site or a solid waste landfill and a mounding analysis is included.

[1] 80% TSS removal is required prior to discharge to infiltration BMP if Dynamic Field method is used.

Checklist (continued)

Standard 3: Recharge (continued)

☐ The infiltration BMP is used to attenuate peak flows during storms greater than or equal to the 10-year 24-hour storm and separation to seasonal high groundwater is less than 4 feet and a mounding analysis is provided.

☐ Documentation is provided showing that infiltration BMPs do not adversely impact nearby wetland resource areas.

Standard 4: Water Quality

The Long-Term Pollution Prevention Plan typically includes the following:

- Good housekeeping practices;
- Provisions for storing materials and waste products inside or under cover;
- Vehicle washing controls;
- Requirements for routine inspections and maintenance of stormwater BMPs;
- Spill prevention and response plans;
- Provisions for maintenance of lawns, gardens, and other landscaped areas;
- Requirements for storage and use of fertilizers, herbicides, and pesticides;
- Pet waste management provisions;
- Provisions for operation and management of septic systems;
- Provisions for solid waste management;
- Snow disposal and plowing plans relative to Wetland Resource Areas;
- Winter Road Salt and/or Sand Use and Storage restrictions;
- Street sweeping schedules;
- Provisions for prevention of illicit discharges to the stormwater management system;
- Documentation that Stormwater BMPs are designed to provide for shutdown and containment in the event of a spill or discharges to or near critical areas or from LUHPPL;
- Training for staff or personnel involved with implementing Long-Term Pollution Prevention Plan;
- List of Emergency contacts for implementing Long-Term Pollution Prevention Plan.

☒ A Long-Term Pollution Prevention Plan is attached to Stormwater Report and is included as an attachment to the Wetlands Notice of Intent.

☒ Treatment BMPs subject to the 44% TSS removal pretreatment requirement and the one inch rule for calculating the water quality volume are included, and discharge:

- ☐ is within the Zone II or Interim Wellhead Protection Area
- ☐ is near or to other critical areas
- ☐ is within soils with a rapid infiltration rate (greater than 2.4 inches per hour)
- ☒ involves runoff from land uses with higher potential pollutant loads.

☐ The Required Water Quality Volume is reduced through use of the LID site Design Credits.

☒ Calculations documenting that the treatment train meets the 80% TSS removal requirement and, if applicable, the 44% TSS removal pretreatment requirement, are provided.

Checklist (continued)

Standard 4: Water Quality (continued)

☒ The BMP is sized (and calculations provided) based on:

☒ The ½" or 1" Water Quality Volume or

☐ The equivalent flow rate associated with the Water Quality Volume and documentation is provided showing that the BMP treats the required water quality volume.

☒ The applicant proposes to use proprietary BMPs, and documentation supporting use of proprietary BMP and proposed TSS removal rate is provided. This documentation may be in the form of the propriety BMP checklist found in Volume 2, Chapter 4 of the Massachusetts Stormwater Handbook and submitting copies of the TARP Report, STEP Report, and/or other third party studies verifying performance of the proprietary BMPs.

☐ A TMDL exists that indicates a need to reduce pollutants other than TSS and documentation showing that the BMPs selected are consistent with the TMDL is provided.

Standard 5: Land Uses With Higher Potential Pollutant Loads (LUHPPLs)

☐ The NPDES Multi-Sector General Permit covers the land use and the Stormwater Pollution Prevention Plan (SWPPP) has been included with the Stormwater Report.

☐ The NPDES Multi-Sector General Permit covers the land use and the SWPPP will be submitted ***prior to*** the discharge of stormwater to the post-construction stormwater BMPs.

☐ The NPDES Multi-Sector General Permit does ***not*** cover the land use.

☒ LUHPPLs are located at the site and industry specific source control and pollution prevention measures have been proposed to reduce or eliminate the exposure of LUHPPLs to rain, snow, snow melt and runoff, and been included in the long term Pollution Prevention Plan.

☐ All exposure has been eliminated.

☐ All exposure has ***not*** been eliminated and all BMPs selected are on MassDEP LUHPPL list.

☒ The LUHPPL has the potential to generate runoff with moderate to higher concentrations of oil and grease (e.g. all parking lots with >1000 vehicle trips per day) and the treatment train includes an oil grit separator, a filtering bioretention area, a sand filter or equivalent.

Standard 6: Critical Areas

☐ The discharge is near or to a critical area and the treatment train includes only BMPs that MassDEP has approved for stormwater discharges to or near that particular class of critical area.

☐ Critical areas and BMPs are identified in the Stormwater Report.

Checklist (continued)

Standard 7: Redevelopments and Other Projects Subject to the Standards only to the maximum extent practicable

☒ The project is subject to the Stormwater Management Standards only to the maximum Extent Practicable as a:

- ☐ Limited Project
- ☐ Small Residential Projects: 5-9 single family houses or 5-9 units in a multi-family development provided there is no discharge that may potentially affect a critical area.
- ☐ Small Residential Projects: 2-4 single family houses or 2-4 units in a multi-family development with a discharge to a critical area
- ☐ Marina and/or boatyard provided the hull painting, service and maintenance areas are protected from exposure to rain, snow, snow melt and runoff
- ☐ Bike Path and/or Foot Path
- ☒ Redevelopment Project
- ☐ Redevelopment portion of mix of new and redevelopment.

☐ Certain standards are not fully met (Standard No. 1, 8, 9, and 10 must always be fully met) and an explanation of why these standards are not met is contained in the Stormwater Report.

☒ The project involves redevelopment and a description of all measures that have been taken to improve existing conditions is provided in the Stormwater Report. The redevelopment checklist found in Volume 2 Chapter 3 of the Massachusetts Stormwater Handbook may be used to document that the proposed stormwater management system (a) complies with Standards 2, 3 and the pretreatment and structural BMP requirements of Standards 4-6 to the maximum extent practicable and (b) improves existing conditions.

Standard 8: Construction Period Pollution Prevention and Erosion and Sedimentation Control

A Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan must include the following information:

- Narrative;
- Construction Period Operation and Maintenance Plan;
- Names of Persons or Entity Responsible for Plan Compliance;
- Construction Period Pollution Prevention Measures;
- Erosion and Sedimentation Control Plan Drawings;
- Detail drawings and specifications for erosion control BMPs, including sizing calculations;
- Vegetation Planning;
- Site Development Plan;
- Construction Sequencing Plan;
- Sequencing of Erosion and Sedimentation Controls;
- Operation and Maintenance of Erosion and Sedimentation Controls;
- Inspection Schedule;
- Maintenance Schedule;
- Inspection and Maintenance Log Form.

☒ A Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan containing the information set forth above has been included in the Stormwater Report.

Massachusetts Department of Environmental Protection
Bureau of Resource Protection - Wetlands Program

Checklist for Stormwater Report

Checklist (continued)

Standard 8: Construction Period Pollution Prevention and Erosion and Sedimentation Control (continued)

☐ The project is highly complex and information is included in the Stormwater Report that explains why it is not possible to submit the Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan with the application. A Construction Period Pollution Prevention and Erosion and Sedimentation Control has ***not*** been included in the Stormwater Report but will be submitted ***before*** land disturbance begins.

☒ The project is ***not*** covered by a NPDES Construction General Permit.

☐ The project is covered by a NPDES Construction General Permit and a copy of the SWPPP is in the Stormwater Report.

☐ The project is covered by a NPDES Construction General Permit but no SWPPP been submitted. The SWPPP will be submitted BEFORE land disturbance begins.

Standard 9: Operation and Maintenance Plan

☒ The Post Construction Operation and Maintenance Plan is included in the Stormwater Report and includes the following information:

- ☒ Name of the stormwater management system owners;
- ☒ Party responsible for operation and maintenance;
- ☒ Schedule for implementation of routine and non-routine maintenance tasks;
- ☒ Plan showing the location of all stormwater BMPs maintenance access areas;
- ☐ Description and delineation of public safety features;
- ☐ Estimated operation and maintenance budget; and
- ☒ Operation and Maintenance Log Form.

☐ The responsible party is ***not*** the owner of the parcel where the BMP is located and the Stormwater Report includes the following submissions:

- ☐ A copy of the legal instrument (deed, homeowner's association, utility trust or other legal entity) that establishes the terms of and legal responsibility for the operation and maintenance of the project site stormwater BMPs;
- ☐ A plan and easement deed that allows site access for the legal entity to operate and maintain BMP functions.

Standard 10: Prohibition of Illicit Discharges

☐ The Long-Term Pollution Prevention Plan includes measures to prevent illicit discharges;

☒ An Illicit Discharge Compliance Statement is attached;

☐ NO Illicit Discharge Compliance Statement is attached but will be submitted ***prior to*** the discharge of any stormwater to post-construction BMPs.

MHF Design Consultants, Inc.
44 Stiles Road • Suite One • Salem, New Hampshire 03079
TEL (603) 893-0720 • FAX (603) 893-0733
www.mhfdesign.com

November 7, 2017

Town of Grafton Conservation Commission
30 Providence Road
Grafton, MA 01519

Re: 88 Worcester Street
Map 55 Lot 94
Sub: Illicit Discharge Statement
Standard #10

Dear Commission Members:

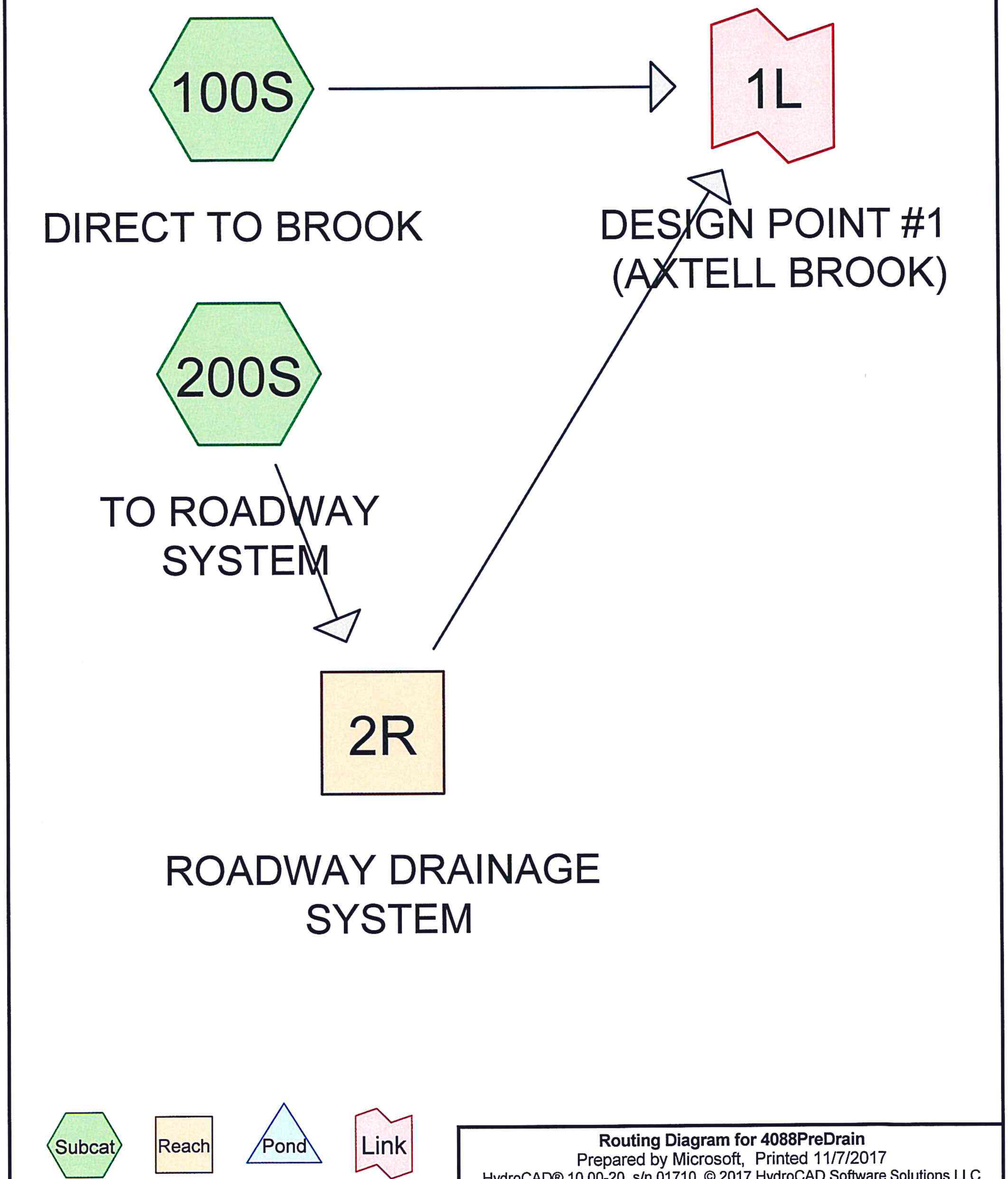
On behalf of our client, Petrogas Group New England, Inc., we hereby state that to the best of our knowledge, no illicit discharges exist on the above referenced site and none are proposed with the site re-development plans. Implementing the pollution prevention plan measures outlined in the site redevelopment plans will prevent illicit discharges to the stormwater management system, including wastewater discharges and discharges of stormwater contaminated by contact with process wastes, raw materials, toxic pollutants, hazardous substances, oil, or grease. Refer to the Grading & Drainage Plan from the site plan set for additional information.

Sincerely,
MHF Design Consultants, Inc.

David R. Jordan, PE, PLS, LEED AP
Sr. Project Manager

APPENDIX F

Pre-Development HydroCAD Printouts



Routing Diagram for 4088PreDrain
Prepared by Microsoft, Printed 11/7/2017
HydroCAD® 10.00-20 s/n 01710 © 2017 HydroCAD Software Solutions LLC

Area Listing (all nodes)

Area (sq-ft)	CN	Description (subcatchment-numbers)
6,005	39	>75% Grass cover, Good, HSG A (100S, 200S)
2,411	96	Gravel surface, HSG A (100S)
18,528	98	Paved parking, HSG A (100S, 200S)
3,050	98	Roofs, HSG A (100S, 200S)
2,650	30	Woods, Good, HSG A (100S)
32,644	**81**	**TOTAL AREA**

Soil Listing (all nodes)

Area (sq-ft)	Soil Group	Subcatchment Numbers
32,644	HSG A	100S, 200S
0	HSG B	
0	HSG C	
0	HSG D	
0	Other	
32,644		**TOTAL AREA**

Ground Covers (all nodes)

HSG-A (sq-ft)	HSG-B (sq-ft)	HSG-C (sq-ft)	HSG-D (sq-ft)	Other (sq-ft)	Total (sq-ft)	Ground Cover
6,005	0	0	0	0	6,005	>75% Grass cover, Good
2,411	0	0	0	0	2,411	Gravel surface
18,528	0	0	0	0	18,528	Paved parking
3,050	0	0	0	0	3,050	Roofs
2,650	0	0	0	0	2,650	Woods, Good
32,644	**0**	**0**	**0**	**0**	**32,644**	**TOTAL AREA**

Time span=0.00-30.00 hrs, dt=0.01 hrs, 3001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment 100S: DIRECT TO BROOK Runoff Area=23,824 sf 55.47% Impervious Runoff Depth=1.02"
Flow Length=50' Tc=3.4 min CN=76 Runoff=0.68 cfs 2,015 cf

Subcatchment 200S: TO ROADWAY Runoff Area=8,820 sf 94.81% Impervious Runoff Depth=2.45"
Flow Length=115' Slope=0.0140 '/' Tc=1.1 min CN=95 Runoff=0.66 cfs 1,800 cf

Reach 2R: ROADWAY DRAINAGE SYSTEM Inflow=0.66 cfs 1,800 cf
Outflow=0.66 cfs 1,800 cf

Link 1L: DESIGN POINT #1 (AXTELL BROOK) Inflow=1.25 cfs 3,815 cf
Primary=1.25 cfs 3,815 cf

Total Runoff Area = 32,644 sf Runoff Volume = 3,815 cf Average Runoff Depth = 1.40"
33.90% Pervious = 11,066 sf 66.10% Impervious = 21,578 sf

Summary for Subcatchment 100S: DIRECT TO BROOK

Runoff = 0.68 cfs @ 12.06 hrs, Volume= 2,015 cf, Depth= 1.02"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-yr Rainfall=3.00"

Area (sf)	CN	Description
2,650	30	Woods, Good, HSG A
2,411	96	Gravel surface, HSG A
2,083	98	Roofs, HSG A
5,547	39	>75% Grass cover, Good, HSG A
11,133	98	Paved parking, HSG A
23,824	76	Weighted Average
10,608		44.53% Pervious Area
13,216		55.47% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.3	25	0.0200	0.12		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.00"
0.1	25	0.1600	6.44		**Shallow Concentrated Flow,** Unpaved Kv= 16.1 fps
3.4	50	Total			

Summary for Subcatchment 200S: TO ROADWAY SYSTEM

[49] Hint: Tc<2dt may require smaller dt

Runoff = 0.66 cfs @ 12.02 hrs, Volume= 1,800 cf, Depth= 2.45"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-yr Rainfall=3.00"

Area (sf)	CN	Description
967	98	Roofs, HSG A
458	39	>75% Grass cover, Good, HSG A
7,395	98	Paved parking, HSG A
8,820	95	Weighted Average
458		5.19% Pervious Area
8,362		94.81% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.5	25	0.0140	0.88		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 3.00"
0.6	90	0.0140	2.40		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
1.1	115	Total			

Summary for Reach 2R: ROADWAY DRAINAGE SYSTEM

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area =	8,820 sf,	94.81% Impervious,	Inflow Depth = 2.45"	for 2-yr event
Inflow =	0.66 cfs @	12.02 hrs, Volume=	1,800 cf	
Outflow =	0.66 cfs @	12.02 hrs, Volume=	1,800 cf,	Atten= 0%, Lag= 0.0 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs

Summary for Link 1L: DESIGN POINT #1 (AXTELL BROOK)

Inflow Area =	32,644 sf,	66.10% Impervious,	Inflow Depth = 1.40"	for 2-yr event
Inflow =	1.25 cfs @	12.04 hrs, Volume=	3,815 cf	
Primary =	1.25 cfs @	12.04 hrs, Volume=	3,815 cf,	Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs

Time span=0.00-30.00 hrs, dt=0.01 hrs, 3001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment 100S: DIRECT TO BROOK Runoff Area=23,824 sf 55.47% Impervious Runoff Depth=2.13"
Flow Length=50' Tc=3.4 min CN=76 Runoff=1.50 cfs 4,228 cf

Subcatchment 200S: TO ROADWAY Runoff Area=8,820 sf 94.81% Impervious Runoff Depth=3.92"
Flow Length=115' Slope=0.0140 '/' Tc=1.1 min CN=95 Runoff=1.02 cfs 2,885 cf

Reach 2R: ROADWAY DRAINAGE SYSTEM Inflow=1.02 cfs 2,885 cf
Outflow=1.02 cfs 2,885 cf

Link 1L: DESIGN POINT #1 (AXTELL BROOK) Inflow=2.38 cfs 7,113 cf
Primary=2.38 cfs 7,113 cf

Total Runoff Area = 32,644 sf Runoff Volume = 7,113 cf Average Runoff Depth = 2.61"
33.90% Pervious = 11,066 sf 66.10% Impervious = 21,578 sf

Summary for Subcatchment 100S: DIRECT TO BROOK

Runoff = 1.50 cfs @ 12.05 hrs, Volume= 4,228 cf, Depth= 2.13"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.50"

Area (sf)	CN	Description
2,650	30	Woods, Good, HSG A
2,411	96	Gravel surface, HSG A
2,083	98	Roofs, HSG A
5,547	39	>75% Grass cover, Good, HSG A
11,133	98	Paved parking, HSG A
23,824	76	Weighted Average
10,608		44.53% Pervious Area
13,216		55.47% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.3	25	0.0200	0.12		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.00"
0.1	25	0.1600	6.44		**Shallow Concentrated Flow,** Unpaved Kv= 16.1 fps
3.4	50	Total			

Summary for Subcatchment 200S: TO ROADWAY SYSTEM

[49] Hint: Tc<2dt may require smaller dt

Runoff = 1.02 cfs @ 12.02 hrs, Volume= 2,885 cf, Depth= 3.92"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.50"

Area (sf)	CN	Description
967	98	Roofs, HSG A
458	39	>75% Grass cover, Good, HSG A
7,395	98	Paved parking, HSG A
8,820	95	Weighted Average
458		5.19% Pervious Area
8,362		94.81% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.5	25	0.0140	0.88		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 3.00"
0.6	90	0.0140	2.40		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
1.1	115	Total			

Summary for Reach 2R: ROADWAY DRAINAGE SYSTEM

[40] Hint: Not Described (Outflow=Inflow)

```
Inflow Area =        8,820 sf,  94.81% Impervious,  Inflow Depth =  3.92"   for  10-yr event
Inflow      =       1.02 cfs @  12.02 hrs,  Volume=           2,885 cf
Outflow     =       1.02 cfs @  12.02 hrs,  Volume=           2,885 cf,  Atten= 0%,  Lag= 0.0 min
```

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs

Summary for Link 1L: DESIGN POINT #1 (AXTELL BROOK)

```
Inflow Area =       32,644 sf,  66.10% Impervious,  Inflow Depth =  2.61"   for  10-yr event
Inflow      =       2.38 cfs @  12.04 hrs,  Volume=           7,113 cf
Primary     =       2.38 cfs @  12.04 hrs,  Volume=           7,113 cf,  Atten= 0%,  Lag= 0.0 min
```

Primary outflow = Inflow, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs

Time span=0.00-30.00 hrs, dt=0.01 hrs, 3001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment 100S: DIRECT TO BROOK Runoff Area=23,824 sf 55.47% Impervious Runoff Depth=3.82"
Flow Length=50' Tc=3.4 min CN=76 Runoff=2.69 cfs 7,575 cf

Subcatchment 200S: TO ROADWAY Runoff Area=8,820 sf 94.81% Impervious Runoff Depth=5.91"
Flow Length=115' Slope=0.0140 '/' Tc=1.1 min CN=95 Runoff=1.51 cfs 4,343 cf

Reach 2R: ROADWAY DRAINAGE SYSTEM
Inflow=1.51 cfs 4,343 cf
Outflow=1.51 cfs 4,343 cf

Link 1L: DESIGN POINT #1 (AXTELL BROOK)
Inflow=3.99 cfs 11,917 cf
Primary=3.99 cfs 11,917 cf

Total Runoff Area = 32,644 sf Runoff Volume = 11,917 cf Average Runoff Depth = 4.38"
33.90% Pervious = 11,066 sf 66.10% Impervious = 21,578 sf

Summary for Subcatchment 100S: DIRECT TO BROOK

Runoff = 2.69 cfs @ 12.05 hrs, Volume= 7,575 cf, Depth= 3.82"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-yr Rainfall=6.50"

Area (sf)	CN	Description
2,650	30	Woods, Good, HSG A
2,411	96	Gravel surface, HSG A
2,083	98	Roofs, HSG A
5,547	39	>75% Grass cover, Good, HSG A
11,133	98	Paved parking, HSG A
23,824	76	Weighted Average
10,608		44.53% Pervious Area
13,216		55.47% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.3	25	0.0200	0.12		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.00"
0.1	25	0.1600	6.44		**Shallow Concentrated Flow,** Unpaved Kv= 16.1 fps
3.4	50	Total			

Summary for Subcatchment 200S: TO ROADWAY SYSTEM

[49] Hint: Tc<2dt may require smaller dt

Runoff = 1.51 cfs @ 12.02 hrs, Volume= 4,343 cf, Depth= 5.91"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-yr Rainfall=6.50"

Area (sf)	CN	Description
967	98	Roofs, HSG A
458	39	>75% Grass cover, Good, HSG A
7,395	98	Paved parking, HSG A
8,820	95	Weighted Average
458		5.19% Pervious Area
8,362		94.81% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.5	25	0.0140	0.88		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 3.00"
0.6	90	0.0140	2.40		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
1.1	115	Total			

Summary for Reach 2R: ROADWAY DRAINAGE SYSTEM

[40] Hint: Not Described (Outflow=Inflow)

```
Inflow Area =      8,820 sf,  94.81% Impervious,  Inflow Depth =  5.91"   for  100-yr event
Inflow      =    1.51 cfs @  12.02 hrs,  Volume=          4,343 cf
Outflow     =    1.51 cfs @  12.02 hrs,  Volume=          4,343 cf,  Atten= 0%,  Lag= 0.0 min
```

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs

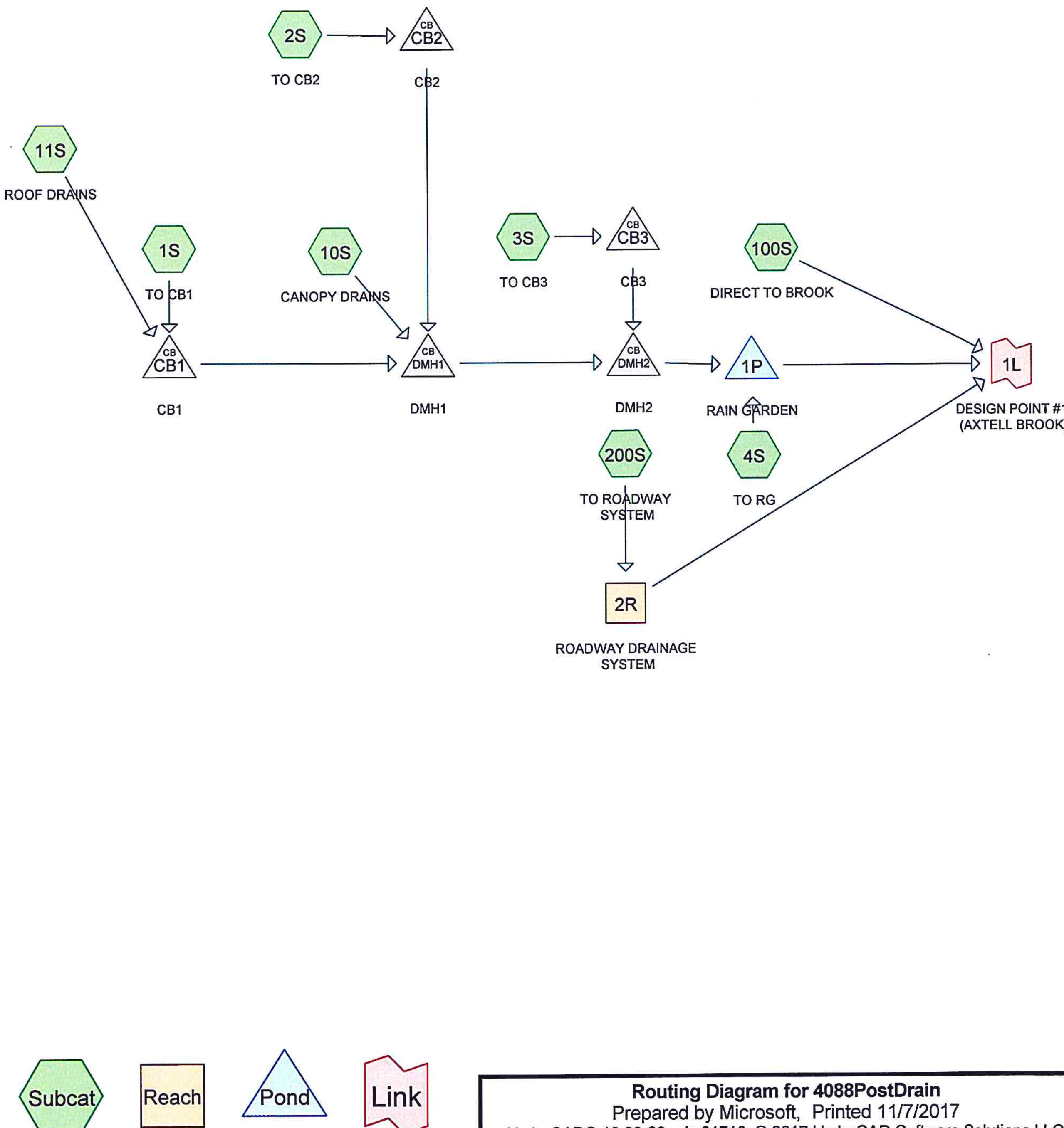
Summary for Link 1L: DESIGN POINT #1 (AXTELL BROOK)

```
Inflow Area =     32,644 sf,  66.10% Impervious,  Inflow Depth =  4.38"   for  100-yr event
Inflow      =    3.99 cfs @  12.04 hrs,  Volume=         11,917 cf
Primary     =    3.99 cfs @  12.04 hrs,  Volume=         11,917 cf,  Atten= 0%,  Lag= 0.0 min
```

Primary outflow = Inflow, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs

APPENDIX G

Post-Development HydroCAD Printouts



Routing Diagram for 4088PostDrain
Prepared by Microsoft, Printed 11/7/2017
HydroCAD® 10.00-20 s/n 01710 © 2017 HydroCAD Software Solutions LLC

Area Listing (all nodes)

Area (sq-ft)	CN	Description (subcatchment-numbers)
12,155	39	>75% Grass cover, Good, HSG A (4S, 100S, 200S)
13,755	98	Paved parking, HSG A (1S, 2S, 3S, 200S)
4,083	98	Roofs, HSG A (10S, 11S)
2,650	30	Woods, Good, HSG A (100S)
32,643	**71**	**TOTAL AREA**

Soil Listing (all nodes)

Area (sq-ft)	Soil Group	Subcatchment Numbers
32,643	HSG A	1S, 2S, 3S, 4S, 10S, 11S, 100S, 200S
0	HSG B	
0	HSG C	
0	HSG D	
0	Other	
32,643		**TOTAL AREA**

Ground Covers (all nodes)

HSG-A (sq-ft)	HSG-B (sq-ft)	HSG-C (sq-ft)	HSG-D (sq-ft)	Other (sq-ft)	Total (sq-ft)	Ground Cover
12,155	0	0	0	0	12,155	>75% Grass cover, Good
13,755	0	0	0	0	13,755	Paved parking
4,083	0	0	0	0	4,083	Roofs
2,650	0	0	0	0	2,650	Woods, Good
32,643	**0**	**0**	**0**	**0**	**32,643**	**TOTAL AREA**

Pipe Listing (all nodes)

Line#	Node Number	In-Invert (feet)	Out-Invert (feet)	Length (feet)	Slope (ft/ft)	n	Diam/Width (inches)	Height (inches)	Inside-Fill (inches)
1	CB1	306.75	306.25	103.0	0.0049	0.013	12.0	0.0	0.0
2	CB2	306.75	306.25	105.0	0.0048	0.013	12.0	0.0	0.0
3	CB3	306.25	306.15	10.0	0.0100	0.013	12.0	0.0	0.0
4	DMH1	306.25	306.15	16.0	0.0063	0.013	15.0	0.0	0.0
5	DMH2	306.15	306.00	15.0	0.0100	0.013	15.0	0.0	0.0

Time span=0.00-30.00 hrs, dt=0.01 hrs, 3001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment 1S: TO CB1 Runoff Area=4,283 sf 100.00% Impervious Runoff Depth=2.77"
Flow Length=70' Slope=0.0100 '/' Tc=0.9 min CN=98 Runoff=0.34 cfs 988 cf

Subcatchment 2S: TO CB2 Runoff Area=5,578 sf 100.00% Impervious Runoff Depth=2.77"
Flow Length=110' Slope=0.0110 '/' Tc=1.2 min CN=98 Runoff=0.44 cfs 1,287 cf

Subcatchment 3S: TO CB3 Runoff Area=2,125 sf 100.00% Impervious Runoff Depth=2.77"
Flow Length=50' Slope=0.0130 '/' Tc=0.7 min CN=98 Runoff=0.17 cfs 490 cf

Subcatchment 4S: TO RG Runoff Area=2,395 sf 0.00% Impervious Runoff Depth=0.00"
Flow Length=15' Slope=0.0200 '/' Tc=2.2 min CN=39 Runoff=0.00 cfs 0 cf

Subcatchment 10S: CANOPY DRAINS Runoff Area=2,000 sf 100.00% Impervious Runoff Depth=2.77"
Tc=0.0 min CN=98 Runoff=0.16 cfs 461 cf

Subcatchment 11S: ROOF DRAINS Runoff Area=2,083 sf 100.00% Impervious Runoff Depth=2.77"
Tc=0.0 min CN=98 Runoff=0.17 cfs 481 cf

Subcatchment 100S: DIRECT TO BROOK Runoff Area=11,099 sf 0.00% Impervious Runoff Depth=0.00"
Flow Length=50' Tc=3.4 min CN=37 Runoff=0.00 cfs 0 cf

Subcatchment 200S: TO ROADWAY Runoff Area=3,080 sf 57.44% Impervious Runoff Depth=0.86"
Flow Length=76' Tc=0.7 min CN=73 Runoff=0.08 cfs 220 cf

Reach 2R: ROADWAY DRAINAGE SYSTEM Inflow=0.08 cfs 220 cf
Outflow=0.08 cfs 220 cf

Pond 1P: RAIN GARDEN Peak Elev=308.86' Storage=1,297 cf Inflow=1.26 cfs 3,705 cf
Discarded=0.12 cfs 3,329 cf Primary=0.36 cfs 376 cf Outflow=0.48 cfs 3,705 cf

Pond CB1: CB1 Peak Elev=308.88' Inflow=0.50 cfs 1,469 cf
12.0" Round Culvert n=0.013 L=103.0' S=0.0049 '/' Outflow=0.50 cfs 1,469 cf

Pond CB2: CB2 Peak Elev=308.88' Inflow=0.44 cfs 1,287 cf
12.0" Round Culvert n=0.013 L=105.0' S=0.0048 '/' Outflow=0.44 cfs 1,287 cf

Pond CB3: CB3 Peak Elev=308.87' Inflow=0.17 cfs 490 cf
12.0" Round Culvert n=0.013 L=10.0' S=0.0100 '/' Outflow=0.18 cfs 489 cf

Pond DMH1: DMH1 Peak Elev=308.87' Inflow=1.09 cfs 3,217 cf
15.0" Round Culvert n=0.013 L=16.0' S=0.0063 '/' Outflow=1.09 cfs 3,217 cf

Pond DMH2: DMH2 Peak Elev=308.87' Inflow=1.26 cfs 3,706 cf
15.0" Round Culvert n=0.013 L=15.0' S=0.0100 '/' Outflow=1.26 cfs 3,705 cf

Link 1L: DESIGN POINT #1 (AXTELL BROOK) Inflow=0.40 cfs 596 cf
Primary=0.40 cfs 596 cf

Total Runoff Area = 32,643 sf Runoff Volume = 3,927 cf Average Runoff Depth = 1.44"
45.35% Pervious = 14,805 sf 54.65% Impervious = 17,838 sf

Summary for Subcatchment 1S: TO CB1

[49] Hint: Tc<2dt may require smaller dt

Runoff = 0.34 cfs @ 12.01 hrs, Volume= 988 cf, Depth= 2.77"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-yr Rainfall=3.00"

Area (sf)	CN	Description
4,283	98	Paved parking, HSG A
4,283		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.5	25	0.0100	0.76		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 3.00"
0.4	45	0.0100	2.03		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
0.9	70	Total			

Summary for Subcatchment 2S: TO CB2

Runoff = 0.44 cfs @ 12.02 hrs, Volume= 1,287 cf, Depth= 2.77"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-yr Rainfall=3.00"

Area (sf)	CN	Description
5,578	98	Paved parking, HSG A
5,578		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.5	25	0.0110	0.79		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 3.00"
0.7	85	0.0110	2.13		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
1.2	110	Total			

Summary for Subcatchment 3S: TO CB3

[49] Hint: Tc<2dt may require smaller dt

Runoff = 0.17 cfs @ 12.01 hrs, Volume= 490 cf, Depth= 2.77"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-yr Rainfall=3.00"

Area (sf)	CN	Description
2,125	98	Paved parking, HSG A
2,125		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.5	25	0.0130	0.85		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 3.00"
0.2	25	0.0130	2.31		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
0.7	50	Total			

Summary for Subcatchment 4S: TO RG

[45] Hint: Runoff=Zero

Runoff = 0.00 cfs @ 0.00 hrs, Volume= 0 cf, Depth= 0.00"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-yr Rainfall=3.00"

Area (sf)	CN	Description
2,395	39	>75% Grass cover, Good, HSG A
2,395		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.2	15	0.0200	0.11		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.00"

Summary for Subcatchment 10S: CANOPY DRAINS

[46] Hint: Tc=0 (Instant runoff peak depends on dt)

Runoff = 0.16 cfs @ 12.00 hrs, Volume= 461 cf, Depth= 2.77"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-yr Rainfall=3.00"

Area (sf)	CN	Description
2,000	98	Roofs, HSG A
2,000		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0					**Direct Entry,**

Summary for Subcatchment 11S: ROOF DRAINS

[46] Hint: Tc=0 (Instant runoff peak depends on dt)

Runoff = 0.17 cfs @ 12.00 hrs, Volume= 481 cf, Depth= 2.77"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-yr Rainfall=3.00"

Area (sf)	CN	Description
2,083	98	Roofs, HSG A
2,083		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0					**Direct Entry,**

Summary for Subcatchment 100S: DIRECT TO BROOK

[45] Hint: Runoff=Zero

Runoff = 0.00 cfs @ 0.00 hrs, Volume= 0 cf, Depth= 0.00"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-yr Rainfall=3.00"

Area (sf)	CN	Description
2,650	30	Woods, Good, HSG A
8,449	39	>75% Grass cover, Good, HSG A
11,099	37	Weighted Average
11,099		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.3	25	0.0200	0.12		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.00"
0.1	25	0.1600	6.44		**Shallow Concentrated Flow,** Unpaved Kv= 16.1 fps
3.4	50	Total			

Summary for Subcatchment 200S: TO ROADWAY SYSTEM

[49] Hint: Tc<2dt may require smaller dt

Runoff = 0.08 cfs @ 12.01 hrs, Volume= 220 cf, Depth= 0.86"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-yr Rainfall=3.00"

Area (sf)	CN	Description
1,311	39	>75% Grass cover, Good, HSG A
1,769	98	Paved parking, HSG A
3,080	73	Weighted Average
1,311		42.56% Pervious Area
1,769		57.44% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.2	20	0.0500	1.39		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 3.00"
0.5	56	0.0100	2.03		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
0.7	76	Total			

Summary for Reach 2R: ROADWAY DRAINAGE SYSTEM

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 3,080 sf, 57.44% Impervious, Inflow Depth = 0.86" for 2-yr event
Inflow = 0.08 cfs @ 12.01 hrs, Volume= 220 cf
Outflow = 0.08 cfs @ 12.01 hrs, Volume= 220 cf, Atten= 0%, Lag= 0.0 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs

Summary for Pond 1P: RAIN GARDEN

RAWLS RATE FOR LOAMY SAND = 2.41 in/hr

[80] Warning: Exceeded Pond DMH2 by 1.54' @ 17.36 hrs (5.21 cfs 8,537 cf)

Inflow Area = 18,464 sf, 87.03% Impervious, Inflow Depth = 2.41" for 2-yr event
Inflow = 1.26 cfs @ 12.02 hrs, Volume= 3,705 cf
Outflow = 0.48 cfs @ 12.15 hrs, Volume= 3,705 cf, Atten= 62%, Lag= 8.1 min
Discarded = 0.12 cfs @ 12.15 hrs, Volume= 3,329 cf
Primary = 0.36 cfs @ 12.15 hrs, Volume= 376 cf

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Peak Elev= 308.86' @ 12.15 hrs Surf.Area= 936 sf Storage= 1,297 cf
Flood Elev= 310.00' Surf.Area= 1,519 sf Storage= 2,683 cf

Plug-Flow detention time= 116.1 min calculated for 3,704 cf (100% of inflow)
Center-of-Mass det. time= 116.1 min (868.9 - 752.8)

Volume	Invert	Avail.Storage	Storage Description
#1	304.00'	2,683 cf	**Custom Stage Data (Irregular)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Perim. (feet)	Voids (%)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)	Wet.Area (sq-ft)
304.00	80	47.0	0.0	0	0	80
306.00	80	47.0	35.0	56	56	174
308.00	589	109.0	100.0	591	647	959
310.00	1,519	171.0	100.0	2,036	2,683	2,369

Device	Routing	Invert	Outlet Devices
#1	Discarded	304.00'	**2.410 in/hr Exfiltration over Wetted area** Conductivity to Groundwater Elevation = 302.00'
#2	Primary	308.80'	**10.0' long x 9.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 Coef. (English) 2.46 2.55 2.70 2.69 2.68 2.68 2.67 2.64 2.64 2.64 2.65 2.64 2.65 2.65 2.66 2.67 2.69

Discarded OutFlow Max=0.12 cfs @ 12.15 hrs HW=308.86' (Free Discharge)
└─**1=Exfiltration** (Controls 0.12 cfs)

Primary OutFlow Max=0.36 cfs @ 12.15 hrs HW=308.86' TW=0.00' (Dynamic Tailwater)
└─**2=Broad-Crested Rectangular Weir** (Weir Controls 0.36 cfs @ 0.60 fps)

Summary for Pond CB1: CB1

[87] Warning: Oscillations may require smaller dt or Finer Routing (severity=401)

Inflow Area = 6,366 sf,100.00% Impervious, Inflow Depth = 2.77" for 2-yr event
Inflow = 0.50 cfs @ 12.01 hrs, Volume= 1,469 cf
Outflow = 0.50 cfs @ 12.01 hrs, Volume= 1,469 cf, Atten= 0%, Lag= 0.0 min
Primary = 0.50 cfs @ 12.01 hrs, Volume= 1,469 cf

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Peak Elev= 308.88' @ 12.16 hrs
Flood Elev= 309.60'

Device	Routing	Invert	Outlet Devices
#1	Primary	306.75'	**12.0" Round Culvert** L= 103.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 306.75' / 306.25' S= 0.0049 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.79 sf

Primary OutFlow Max=0.00 cfs @ 12.01 hrs HW=308.48' TW=308.50' (Dynamic Tailwater)
└─**1=Culvert** (Controls 0.00 cfs)

Summary for Pond CB2: CB2

[87] Warning: Oscillations may require smaller dt or Finer Routing (severity=419)

```
Inflow Area =        5,578 sf,100.00% Impervious,  Inflow Depth =  2.77"   for  2-yr event
Inflow      =     0.44 cfs @  12.02 hrs,  Volume=          1,287 cf
Outflow     =     0.44 cfs @  12.02 hrs,  Volume=          1,287 cf,  Atten= 0%,  Lag= 0.0 min
Primary     =     0.44 cfs @  12.02 hrs,  Volume=          1,287 cf
```

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Peak Elev= 308.88' @ 12.16 hrs
Flood Elev= 309.25'

Device	Routing	Invert	Outlet Devices
#1	Primary	306.75'	**12.0" Round Culvert** L= 105.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 306.75' / 306.25' S= 0.0048 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.79 sf

Primary OutFlow Max=0.00 cfs @ 12.02 hrs HW=308.52' TW=308.55' (Dynamic Tailwater)
1=Culvert (Controls 0.00 cfs)

Summary for Pond CB3: CB3

[90] Warning: Qout>Qin may require smaller dt or Finer Routing
[87] Warning: Oscillations may require smaller dt or Finer Routing (severity=689)

```
Inflow Area =        2,125 sf,100.00% Impervious,  Inflow Depth =  2.77"   for  2-yr event
Inflow      =     0.17 cfs @  12.01 hrs,  Volume=            490 cf
Outflow     =     0.18 cfs @  12.02 hrs,  Volume=            489 cf,  Atten= 0%,  Lag= 0.5 min
Primary     =     0.18 cfs @  12.02 hrs,  Volume=            489 cf
```

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Peak Elev= 308.87' @ 12.17 hrs
Flood Elev= 309.60'

Device	Routing	Invert	Outlet Devices
#1	Primary	306.25'	**12.0" Round Culvert** L= 10.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 306.25' / 306.15' S= 0.0100 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.79 sf

Primary OutFlow Max=0.00 cfs @ 12.02 hrs HW=308.52' TW=308.57' (Dynamic Tailwater)
1=Culvert (Controls 0.00 cfs)

Summary for Pond DMH1: DMH1

[80] Warning: Exceeded Pond CB1 by 1.31' @ 15.91 hrs (2.72 cfs 9,778 cf)
[80] Warning: Exceeded Pond CB2 by 1.30' @ 16.14 hrs (2.71 cfs 10,034 cf)

```
Inflow Area =       13,944 sf,100.00% Impervious,  Inflow Depth =  2.77"   for  2-yr event
Inflow      =     1.09 cfs @  12.01 hrs,  Volume=          3,217 cf
Outflow     =     1.09 cfs @  12.01 hrs,  Volume=          3,217 cf,  Atten= 0%,  Lag= 0.0 min
Primary     =     1.09 cfs @  12.01 hrs,  Volume=          3,217 cf
```

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Peak Elev= 308.87' @ 12.17 hrs
Flood Elev= 310.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	306.25'	**15.0" Round Culvert** L= 16.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 306.25' / 306.15' S= 0.0063 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 1.23 sf

Primary OutFlow Max=0.00 cfs @ 12.01 hrs HW=308.51' TW=308.53' (Dynamic Tailwater)
└1=Culvert (Controls 0.00 cfs)

Summary for Pond DMH2: DMH2

[80] Warning: Exceeded Pond CB3 by 2.55' @ 12.79 hrs (5.42 cfs 25,171 cf)
[80] Warning: Exceeded Pond DMH1 by 1.88' @ 15.90 hrs (6.14 cfs 33,508 cf)

Inflow Area =	16,069 sf,100.00% Impervious,	Inflow Depth = 2.77"	for 2-yr event	
Inflow =	1.26 cfs @	12.02 hrs, Volume=	3,706 cf	
Outflow =	1.26 cfs @	12.02 hrs, Volume=	3,705 cf,	Atten= 0%, Lag= 0.0 min
Primary =	1.26 cfs @	12.02 hrs, Volume=	3,705 cf	

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Peak Elev= 308.87' @ 12.16 hrs
Flood Elev= 309.90'

Device	Routing	Invert	Outlet Devices
#1	Primary	306.15'	**15.0" Round Culvert** L= 15.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 306.15' / 306.00' S= 0.0100 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 1.23 sf

Primary OutFlow Max=0.00 cfs @ 12.02 hrs HW=308.56' TW=308.56' (Dynamic Tailwater)
└1=Culvert (Controls 0.00 cfs)

Summary for Link 1L: DESIGN POINT #1 (AXTELL BROOK)

Inflow Area =	32,643 sf, 54.65% Impervious,	Inflow Depth = 0.22"	for 2-yr event	
Inflow =	0.40 cfs @	12.15 hrs, Volume=	596 cf	
Primary =	0.40 cfs @	12.15 hrs, Volume=	596 cf,	Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs

Time span=0.00-30.00 hrs, dt=0.01 hrs, 3001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment 1S: TO CB1 Runoff Area=4,283 sf 100.00% Impervious Runoff Depth=4.26"
Flow Length=70' Slope=0.0100 '/' Tc=0.9 min CN=98 Runoff=0.52 cfs 1,522 cf

Subcatchment 2S: TO CB2 Runoff Area=5,578 sf 100.00% Impervious Runoff Depth=4.26"
Flow Length=110' Slope=0.0110 '/' Tc=1.2 min CN=98 Runoff=0.67 cfs 1,982 cf

Subcatchment 3S: TO CB3 Runoff Area=2,125 sf 100.00% Impervious Runoff Depth=4.26"
Flow Length=50' Slope=0.0130 '/' Tc=0.7 min CN=98 Runoff=0.26 cfs 755 cf

Subcatchment 4S: TO RG Runoff Area=2,395 sf 0.00% Impervious Runoff Depth=0.11"
Flow Length=15' Slope=0.0200 '/' Tc=2.2 min CN=39 Runoff=0.00 cfs 22 cf

Subcatchment 10S: CANOPY DRAINS Runoff Area=2,000 sf 100.00% Impervious Runoff Depth=4.26"
Tc=0.0 min CN=98 Runoff=0.25 cfs 711 cf

Subcatchment 11S: ROOF DRAINS Runoff Area=2,083 sf 100.00% Impervious Runoff Depth=4.26"
Tc=0.0 min CN=98 Runoff=0.26 cfs 740 cf

Subcatchment 100S: DIRECT TO BROOK Runoff Area=11,099 sf 0.00% Impervious Runoff Depth=0.07"
Flow Length=50' Tc=3.4 min CN=37 Runoff=0.00 cfs 61 cf

Subcatchment 200S: TO ROADWAY Runoff Area=3,080 sf 57.44% Impervious Runoff Depth=1.90"
Flow Length=76' Tc=0.7 min CN=73 Runoff=0.19 cfs 487 cf

Reach 2R: ROADWAY DRAINAGE SYSTEM Inflow=0.19 cfs 487 cf
Outflow=0.19 cfs 487 cf

Pond 1P: RAIN GARDEN Peak Elev=308.97' Storage=1,399 cf Inflow=1.92 cfs 5,730 cf
Discarded=0.12 cfs 4,243 cf Primary=1.68 cfs 1,487 cf Outflow=1.80 cfs 5,730 cf

Pond CB1: CB1 Peak Elev=309.19' Inflow=0.76 cfs 2,262 cf
12.0" Round Culvert n=0.013 L=103.0' S=0.0049 '/' Outflow=0.76 cfs 2,262 cf

Pond CB2: CB2 Peak Elev=309.18' Inflow=0.67 cfs 1,982 cf
12.0" Round Culvert n=0.013 L=105.0' S=0.0048 '/' Outflow=0.67 cfs 1,982 cf

Pond CB3: CB3 Peak Elev=309.06' Inflow=0.26 cfs 755 cf
12.0" Round Culvert n=0.013 L=10.0' S=0.0100 '/' Outflow=0.27 cfs 753 cf

Pond DMH1: DMH1 Peak Elev=309.13' Inflow=1.65 cfs 4,955 cf
15.0" Round Culvert n=0.013 L=16.0' S=0.0063 '/' Outflow=1.65 cfs 4,955 cf

Pond DMH2: DMH2 Peak Elev=309.06' Inflow=1.92 cfs 5,708 cf
15.0" Round Culvert n=0.013 L=15.0' S=0.0100 '/' Outflow=1.92 cfs 5,708 cf

Link 1L: DESIGN POINT #1 (AXTELL BROOK) Inflow=1.86 cfs 2,035 cf
Primary=1.86 cfs 2,035 cf

Total Runoff Area = 32,643 sf Runoff Volume = 6,280 cf Average Runoff Depth = 2.31"
45.35% Pervious = 14,805 sf 54.65% Impervious = 17,838 sf

Summary for Subcatchment 1S: TO CB1

[49] Hint: Tc<2dt may require smaller dt

Runoff = 0.52 cfs @ 12.01 hrs, Volume= 1,522 cf, Depth= 4.26"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.50"

Area (sf)	CN	Description
4,283	98	Paved parking, HSG A
4,283		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.5	25	0.0100	0.76		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 3.00"
0.4	45	0.0100	2.03		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
0.9	70	Total			

Summary for Subcatchment 2S: TO CB2

Runoff = 0.67 cfs @ 12.02 hrs, Volume= 1,982 cf, Depth= 4.26"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.50"

Area (sf)	CN	Description
5,578	98	Paved parking, HSG A
5,578		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.5	25	0.0110	0.79		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 3.00"
0.7	85	0.0110	2.13		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
1.2	110	Total			

Summary for Subcatchment 3S: TO CB3

[49] Hint: Tc<2dt may require smaller dt

Runoff = 0.26 cfs @ 12.01 hrs, Volume= 755 cf, Depth= 4.26"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.50"

Area (sf)	CN	Description
2,125	98	Paved parking, HSG A
2,125		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.5	25	0.0130	0.85		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 3.00"
0.2	25	0.0130	2.31		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
0.7	50	Total			

Summary for Subcatchment 4S: TO RG

Runoff = 0.00 cfs @ 14.65 hrs, Volume= 22 cf, Depth= 0.11"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.50"

Area (sf)	CN	Description
2,395	39	>75% Grass cover, Good, HSG A
2,395		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.2	15	0.0200	0.11		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.00"

Summary for Subcatchment 10S: CANOPY DRAINS

[46] Hint: Tc=0 (Instant runoff peak depends on dt)

Runoff = 0.25 cfs @ 12.00 hrs, Volume= 711 cf, Depth= 4.26"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.50"

Area (sf)	CN	Description
2,000	98	Roofs, HSG A
2,000		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0					**Direct Entry,**

Summary for Subcatchment 11S: ROOF DRAINS

[46] Hint: Tc=0 (Instant runoff peak depends on dt)

Runoff = 0.26 cfs @ 12.00 hrs, Volume= 740 cf, Depth= 4.26"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.50"

Area (sf)	CN	Description
2,083	98	Roofs, HSG A
2,083		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0					**Direct Entry,**

Summary for Subcatchment 100S: DIRECT TO BROOK

Runoff = 0.00 cfs @ 15.24 hrs, Volume= 61 cf, Depth= 0.07"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.50"

Area (sf)	CN	Description
2,650	30	Woods, Good, HSG A
8,449	39	>75% Grass cover, Good, HSG A
11,099	37	Weighted Average
11,099		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.3	25	0.0200	0.12		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.00"
0.1	25	0.1600	6.44		**Shallow Concentrated Flow,** Unpaved Kv= 16.1 fps
3.4	50	Total			

Summary for Subcatchment 200S: TO ROADWAY SYSTEM

[49] Hint: Tc<2dt may require smaller dt

Runoff = 0.19 cfs @ 12.01 hrs, Volume= 487 cf, Depth= 1.90"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-yr Rainfall=4.50"

Area (sf)	CN	Description
1,311	39	>75% Grass cover, Good, HSG A
1,769	98	Paved parking, HSG A
3,080	73	Weighted Average
1,311		42.56% Pervious Area
1,769		57.44% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.2	20	0.0500	1.39		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 3.00"
0.5	56	0.0100	2.03		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
0.7	76	Total			

Summary for Reach 2R: ROADWAY DRAINAGE SYSTEM

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 3,080 sf, 57.44% Impervious, Inflow Depth = 1.90" for 10-yr event
Inflow = 0.19 cfs @ 12.01 hrs, Volume= 487 cf
Outflow = 0.19 cfs @ 12.01 hrs, Volume= 487 cf, Atten= 0%, Lag= 0.0 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs

Summary for Pond 1P: RAIN GARDEN

RAWLS RATE FOR LOAMY SAND = 2.41 in/hr

[80] Warning: Exceeded Pond DMH2 by 1.42' @ 19.06 hrs (4.78 cfs 21,447 cf)

Inflow Area = 18,464 sf, 87.03% Impervious, Inflow Depth = 3.72" for 10-yr event
Inflow = 1.92 cfs @ 12.01 hrs, Volume= 5,730 cf
Outflow = 1.80 cfs @ 12.03 hrs, Volume= 5,730 cf, Atten= 6%, Lag= 1.1 min
Discarded = 0.12 cfs @ 12.03 hrs, Volume= 4,243 cf
Primary = 1.68 cfs @ 12.03 hrs, Volume= 1,487 cf

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Peak Elev= 308.97' @ 12.03 hrs Surf.Area= 985 sf Storage= 1,399 cf
Flood Elev= 310.00' Surf.Area= 1,519 sf Storage= 2,683 cf

Plug-Flow detention time= 100.4 min calculated for 5,728 cf (100% of inflow)
Center-of-Mass det. time= 100.4 min (846.6 - 746.1)

Volume	Invert	Avail.Storage	Storage Description
#1	304.00'	2,683 cf	**Custom Stage Data (Irregular)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Perim. (feet)	Voids (%)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)	Wet.Area (sq-ft)
304.00	80	47.0	0.0	0	0	80
306.00	80	47.0	35.0	56	56	174
308.00	589	109.0	100.0	591	647	959
310.00	1,519	171.0	100.0	2,036	2,683	2,369

Device	Routing	Invert	Outlet Devices
#1	Discarded	304.00'	**2.410 in/hr Exfiltration over Wetted area** Conductivity to Groundwater Elevation = 302.00'
#2	Primary	308.80'	**10.0' long x 9.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 Coef. (English) 2.46 2.55 2.70 2.69 2.68 2.68 2.67 2.64 2.64 2.64 2.65 2.64 2.65 2.65 2.66 2.67 2.69

Discarded OutFlow Max=0.12 cfs @ 12.03 hrs HW=308.97' (Free Discharge)
└─**1=Exfiltration** (Controls 0.12 cfs)

Primary OutFlow Max=1.68 cfs @ 12.03 hrs HW=308.97' TW=0.00' (Dynamic Tailwater)
└─**2=Broad-Crested Rectangular Weir** (Weir Controls 1.68 cfs @ 1.00 fps)

Summary for Pond CB1: CB1

[87] Warning: Oscillations may require smaller dt or Finer Routing (severity=327)

Inflow Area = 6,366 sf,100.00% Impervious, Inflow Depth = 4.26" for 10-yr event
Inflow = 0.76 cfs @ 12.01 hrs, Volume= 2,262 cf
Outflow = 0.76 cfs @ 12.01 hrs, Volume= 2,262 cf, Atten= 0%, Lag= 0.0 min
Primary = 0.76 cfs @ 12.01 hrs, Volume= 2,262 cf

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Peak Elev= 309.19' @ 12.03 hrs
Flood Elev= 309.60'

Device	Routing	Invert	Outlet Devices
#1	Primary	306.75'	**12.0" Round Culvert** L= 103.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 306.75' / 306.25' S= 0.0049 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.79 sf

Primary OutFlow Max=0.58 cfs @ 12.01 hrs HW=309.15' TW=309.11' (Dynamic Tailwater)
└─**1=Culvert** (Outlet Controls 0.58 cfs @ 0.74 fps)

Summary for Pond CB2: CB2

[87] Warning: Oscillations may require smaller dt or Finer Routing (severity=339)

Inflow Area =	5,578 sf,100.00% Impervious,	Inflow Depth = 4.26"	for 10-yr event
Inflow =	0.67 cfs @ 12.02 hrs, Volume=	1,982 cf	
Outflow =	0.67 cfs @ 12.02 hrs, Volume=	1,982 cf, Atten= 0%, Lag= 0.0 min	
Primary =	0.67 cfs @ 12.02 hrs, Volume=	1,982 cf	

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Peak Elev= 309.18' @ 12.03 hrs
Flood Elev= 309.25'

Device	Routing	Invert	Outlet Devices
#1	Primary	306.75'	**12.0" Round Culvert** L= 105.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 306.75' / 306.25' S= 0.0048 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.79 sf

Primary OutFlow Max=0.53 cfs @ 12.02 hrs HW=309.16' TW=309.13' (Dynamic Tailwater)
↑**1=Culvert** (Outlet Controls 0.53 cfs @ 0.68 fps)

Summary for Pond CB3: CB3

[90] Warning: Qout>Qin may require smaller dt or Finer Routing
[87] Warning: Oscillations may require smaller dt or Finer Routing (severity=728)

Inflow Area =	2,125 sf,100.00% Impervious,	Inflow Depth = 4.26"	for 10-yr event
Inflow =	0.26 cfs @ 12.01 hrs, Volume=	755 cf	
Outflow =	0.27 cfs @ 12.01 hrs, Volume=	753 cf, Atten= 0%, Lag= 0.0 min	
Primary =	0.27 cfs @ 12.01 hrs, Volume=	753 cf	

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Peak Elev= 309.06' @ 12.03 hrs
Flood Elev= 309.60'

Device	Routing	Invert	Outlet Devices
#1	Primary	306.25'	**12.0" Round Culvert** L= 10.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 306.25' / 306.15' S= 0.0100 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.79 sf

Primary OutFlow Max=0.00 cfs @ 12.01 hrs HW=309.04' TW=309.06' (Dynamic Tailwater)
↑**1=Culvert** (Controls 0.00 cfs)

Summary for Pond DMH1: DMH1

[87] Warning: Oscillations may require smaller dt or Finer Routing (severity=13)
[80] Warning: Exceeded Pond CB1 by 1.17' @ 17.79 hrs (2.61 cfs 9,081 cf)
[80] Warning: Exceeded Pond CB2 by 1.13' @ 17.97 hrs (2.51 cfs 8,354 cf)

Inflow Area =	13,944 sf,100.00% Impervious,	Inflow Depth = 4.26"	for 10-yr event
Inflow =	1.65 cfs @ 12.01 hrs, Volume=	4,955 cf	
Outflow =	1.65 cfs @ 12.01 hrs, Volume=	4,955 cf, Atten= 0%, Lag= 0.0 min	
Primary =	1.65 cfs @ 12.01 hrs, Volume=	4,955 cf	

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Peak Elev= 309.13' @ 12.02 hrs
Flood Elev= 310.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	306.25'	**15.0" Round Culvert** L= 16.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 306.25' / 306.15' S= 0.0063 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 1.23 sf

Primary OutFlow Max=1.45 cfs @ 12.01 hrs HW=309.12' TW=309.06' (Dynamic Tailwater)
↑—**1=Culvert** (Inlet Controls 1.45 cfs @ 1.18 fps)

Summary for Pond DMH2: DMH2

[80] Warning: Exceeded Pond CB3 by 2.52' @ 13.82 hrs (5.38 cfs 29,761 cf)
[80] Warning: Exceeded Pond DMH1 by 1.22' @ 19.07 hrs (4.11 cfs 20,697 cf)

Inflow Area =	16,069 sf,100.00% Impervious,	Inflow Depth = 4.26"	for 10-yr event	
Inflow =	1.92 cfs @	12.01 hrs, Volume=	5,708 cf	
Outflow =	1.92 cfs @	12.01 hrs, Volume=	5,708 cf,	Atten= 0%, Lag= 0.0 min
Primary =	1.92 cfs @	12.01 hrs, Volume=	5,708 cf	

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Peak Elev= 309.06' @ 12.02 hrs
Flood Elev= 309.90'

Device	Routing	Invert	Outlet Devices
#1	Primary	306.15'	**15.0" Round Culvert** L= 15.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 306.15' / 306.00' S= 0.0100 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 1.23 sf

Primary OutFlow Max=1.84 cfs @ 12.01 hrs HW=309.06' TW=308.96' (Dynamic Tailwater)
↑—**1=Culvert** (Inlet Controls 1.84 cfs @ 1.50 fps)

Summary for Link 1L: DESIGN POINT #1 (AXTELL BROOK)

Inflow Area =	32,643 sf, 54.65% Impervious,	Inflow Depth = 0.75"	for 10-yr event	
Inflow =	1.86 cfs @	12.03 hrs, Volume=	2,035 cf	
Primary =	1.86 cfs @	12.03 hrs, Volume=	2,035 cf,	Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs

Time span=0.00-30.00 hrs, dt=0.01 hrs, 3001 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment 1S: TO CB1 Runoff Area=4,283 sf 100.00% Impervious Runoff Depth=6.26"
Flow Length=70' Slope=0.0100 '/' Tc=0.9 min CN=98 Runoff=0.75 cfs 2,235 cf

Subcatchment 2S: TO CB2 Runoff Area=5,578 sf 100.00% Impervious Runoff Depth=6.26"
Flow Length=110' Slope=0.0110 '/' Tc=1.2 min CN=98 Runoff=0.97 cfs 2,910 cf

Subcatchment 3S: TO CB3 Runoff Area=2,125 sf 100.00% Impervious Runoff Depth=6.26"
Flow Length=50' Slope=0.0130 '/' Tc=0.7 min CN=98 Runoff=0.37 cfs 1,109 cf

Subcatchment 4S: TO RG Runoff Area=2,395 sf 0.00% Impervious Runoff Depth=0.60"
Flow Length=15' Slope=0.0200 '/' Tc=2.2 min CN=39 Runoff=0.02 cfs 119 cf

Subcatchment 10S: CANOPY DRAINS Runoff Area=2,000 sf 100.00% Impervious Runoff Depth=6.26"
Tc=0.0 min CN=98 Runoff=0.36 cfs 1,044 cf

Subcatchment 11S: ROOF DRAINS Runoff Area=2,083 sf 100.00% Impervious Runoff Depth=6.26"
Tc=0.0 min CN=98 Runoff=0.37 cfs 1,087 cf

Subcatchment 100S: DIRECT TO BROOK Runoff Area=11,099 sf 0.00% Impervious Runoff Depth=0.48"
Flow Length=50' Tc=3.4 min CN=37 Runoff=0.05 cfs 440 cf

Subcatchment 200S: TO ROADWAY Runoff Area=3,080 sf 57.44% Impervious Runoff Depth=3.51"
Flow Length=76' Tc=0.7 min CN=73 Runoff=0.35 cfs 900 cf

Reach 2R: ROADWAY DRAINAGE SYSTEM Inflow=0.35 cfs 900 cf
Outflow=0.35 cfs 900 cf

Pond 1P: RAIN GARDEN Peak Elev=309.02' Storage=1,451 cf Inflow=2.80 cfs 8,502 cf
Discarded=0.13 cfs 5,291 cf Primary=2.53 cfs 3,212 cf Outflow=2.66 cfs 8,503 cf

Pond CB1: CB1 Peak Elev=309.51' Inflow=1.10 cfs 3,322 cf
12.0" Round Culvert n=0.013 L=103.0' S=0.0049 '/' Outflow=1.10 cfs 3,322 cf

Pond CB2: CB2 Peak Elev=309.49' Inflow=0.97 cfs 2,910 cf
12.0" Round Culvert n=0.013 L=105.0' S=0.0048 '/' Outflow=0.97 cfs 2,910 cf

Pond CB3: CB3 Peak Elev=309.24' Inflow=0.37 cfs 1,109 cf
12.0" Round Culvert n=0.013 L=10.0' S=0.0100 '/' Outflow=0.40 cfs 1,107 cf

Pond DMH1: DMH1 Peak Elev=309.39' Inflow=2.40 cfs 7,276 cf
15.0" Round Culvert n=0.013 L=16.0' S=0.0063 '/' Outflow=2.40 cfs 7,276 cf

Pond DMH2: DMH2 Peak Elev=309.23' Inflow=2.79 cfs 8,383 cf
15.0" Round Culvert n=0.013 L=15.0' S=0.0100 '/' Outflow=2.79 cfs 8,383 cf

Link 1L: DESIGN POINT #1 (AXTELL BROOK) Inflow=2.87 cfs 4,553 cf
Primary=2.87 cfs 4,553 cf

Total Runoff Area = 32,643 sf Runoff Volume = 9,844 cf Average Runoff Depth = 3.62"
45.35% Pervious = 14,805 sf 54.65% Impervious = 17,838 sf

Summary for Subcatchment 1S: TO CB1

[49] Hint: Tc<2dt may require smaller dt

Runoff = 0.75 cfs @ 12.01 hrs, Volume= 2,235 cf, Depth= 6.26"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-yr Rainfall=6.50"

Area (sf)	CN	Description
4,283	98	Paved parking, HSG A
4,283		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.5	25	0.0100	0.76		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 3.00"
0.4	45	0.0100	2.03		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
0.9	70	Total			

Summary for Subcatchment 2S: TO CB2

Runoff = 0.97 cfs @ 12.02 hrs, Volume= 2,910 cf, Depth= 6.26"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-yr Rainfall=6.50"

Area (sf)	CN	Description
5,578	98	Paved parking, HSG A
5,578		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.5	25	0.0110	0.79		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 3.00"
0.7	85	0.0110	2.13		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
1.2	110	Total			

Summary for Subcatchment 3S: TO CB3

[49] Hint: Tc<2dt may require smaller dt

Runoff = 0.37 cfs @ 12.01 hrs, Volume= 1,109 cf, Depth= 6.26"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-yr Rainfall=6.50"

Area (sf)	CN	Description
2,125	98	Paved parking, HSG A
2,125		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.5	25	0.0130	0.85		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 3.00"
0.2	25	0.0130	2.31		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
0.7	50	Total			

Summary for Subcatchment 4S: TO RG

Runoff = 0.02 cfs @ 12.09 hrs, Volume= 119 cf, Depth= 0.60"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-yr Rainfall=6.50"

Area (sf)	CN	Description
2,395	39	>75% Grass cover, Good, HSG A
2,395		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.2	15	0.0200	0.11		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.00"

Summary for Subcatchment 10S: CANOPY DRAINS

[46] Hint: Tc=0 (Instant runoff peak depends on dt)

Runoff = 0.36 cfs @ 12.00 hrs, Volume= 1,044 cf, Depth= 6.26"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-yr Rainfall=6.50"

Area (sf)	CN	Description
2,000	98	Roofs, HSG A
2,000		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0					**Direct Entry,**

Summary for Subcatchment 11S: ROOF DRAINS

[46] Hint: Tc=0 (Instant runoff peak depends on dt)

Runoff = 0.37 cfs @ 12.00 hrs, Volume= 1,087 cf, Depth= 6.26"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-yr Rainfall=6.50"

Area (sf)	CN	Description
2,083	98	Roofs, HSG A
2,083		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0					**Direct Entry,**

Summary for Subcatchment 100S: DIRECT TO BROOK

Runoff = 0.05 cfs @ 12.30 hrs, Volume= 440 cf, Depth= 0.48"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-yr Rainfall=6.50"

Area (sf)	CN	Description
2,650	30	Woods, Good, HSG A
8,449	39	>75% Grass cover, Good, HSG A
11,099	37	Weighted Average
11,099		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.3	25	0.0200	0.12		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.00"
0.1	25	0.1600	6.44		**Shallow Concentrated Flow,** Unpaved Kv= 16.1 fps
3.4	50	Total			

Summary for Subcatchment 200S: TO ROADWAY SYSTEM

[49] Hint: Tc<2dt may require smaller dt

Runoff = 0.35 cfs @ 12.01 hrs, Volume= 900 cf, Depth= 3.51"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-yr Rainfall=6.50"

Area (sf)	CN	Description
1,311	39	>75% Grass cover, Good, HSG A
1,769	98	Paved parking, HSG A
3,080	73	Weighted Average
1,311		42.56% Pervious Area
1,769		57.44% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.2	20	0.0500	1.39		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 3.00"
0.5	56	0.0100	2.03		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
0.7	76	Total			

Summary for Reach 2R: ROADWAY DRAINAGE SYSTEM

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 3,080 sf, 57.44% Impervious, Inflow Depth = 3.51" for 100-yr event
Inflow = 0.35 cfs @ 12.01 hrs, Volume= 900 cf
Outflow = 0.35 cfs @ 12.01 hrs, Volume= 900 cf, Atten= 0%, Lag= 0.0 min

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs

Summary for Pond 1P: RAIN GARDEN

RAWLS RATE FOR LOAMY SAND = 2.41 in/hr

[80] Warning: Exceeded Pond DMH2 by 1.56' @ 20.18 hrs (5.27 cfs 21,594 cf)

Inflow Area = 18,464 sf, 87.03% Impervious, Inflow Depth = 5.53" for 100-yr event
Inflow = 2.80 cfs @ 12.01 hrs, Volume= 8,502 cf
Outflow = 2.66 cfs @ 12.03 hrs, Volume= 8,503 cf, Atten= 5%, Lag= 0.9 min
Discarded = 0.13 cfs @ 12.03 hrs, Volume= 5,291 cf
Primary = 2.53 cfs @ 12.03 hrs, Volume= 3,212 cf

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Peak Elev= 309.02' @ 12.03 hrs Surf.Area= 1,009 sf Storage= 1,451 cf
Flood Elev= 310.00' Surf.Area= 1,519 sf Storage= 2,683 cf

Plug-Flow detention time= 89.0 min calculated for 8,500 cf (100% of inflow)
Center-of-Mass det. time= 89.0 min (830.9 - 741.9)

Volume	Invert	Avail.Storage	Storage Description
#1	304.00'	2,683 cf	**Custom Stage Data (Irregular)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Perim. (feet)	Voids (%)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)	Wet.Area (sq-ft)
304.00	80	47.0	0.0	0	0	80
306.00	80	47.0	35.0	56	56	174
308.00	589	109.0	100.0	591	647	959
310.00	1,519	171.0	100.0	2,036	2,683	2,369

Device	Routing	Invert	Outlet Devices
#1	Discarded	304.00'	**2.410 in/hr Exfiltration over Wetted area** Conductivity to Groundwater Elevation = 302.00'
#2	Primary	308.80'	**10.0' long x 9.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 Coef. (English) 2.46 2.55 2.70 2.69 2.68 2.68 2.67 2.64 2.64 2.64 2.65 2.64 2.65 2.65 2.66 2.67 2.69

Discarded OutFlow Max=0.13 cfs @ 12.03 hrs HW=309.02' (Free Discharge)
↑—**1=Exfiltration** (Controls 0.13 cfs)

Primary OutFlow Max=2.52 cfs @ 12.03 hrs HW=309.02' TW=0.00' (Dynamic Tailwater)
↑—**2=Broad-Crested Rectangular Weir** (Weir Controls 2.52 cfs @ 1.15 fps)

Summary for Pond CB1: CB1

Inflow Area =	6,366 sf,100.00% Impervious,	Inflow Depth = 6.26"	for 100-yr event	
Inflow =	1.10 cfs @	12.01 hrs, Volume=	3,322 cf	
Outflow =	1.10 cfs @	12.01 hrs, Volume=	3,322 cf,	Atten= 0%, Lag= 0.0 min
Primary =	1.10 cfs @	12.01 hrs, Volume=	3,322 cf	

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Peak Elev= 309.51' @ 12.03 hrs
Flood Elev= 309.60'

Device	Routing	Invert	Outlet Devices
#1	Primary	306.75'	**12.0" Round Culvert** L= 103.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 306.75' / 306.25' S= 0.0049 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.79 sf

Primary OutFlow Max=0.94 cfs @ 12.01 hrs HW=309.46' TW=309.36' (Dynamic Tailwater)
↑—**1=Culvert** (Outlet Controls 0.94 cfs @ 1.19 fps)

Summary for Pond CB2: CB2

[58] Hint: Peaked 0.24' above defined flood level
[87] Warning: Oscillations may require smaller dt or Finer Routing (severity=248)

Inflow Area =	5,578 sf,100.00% Impervious,	Inflow Depth = 6.26"	for 100-yr event	
Inflow =	0.97 cfs @	12.02 hrs, Volume=	2,910 cf	
Outflow =	0.97 cfs @	12.02 hrs, Volume=	2,910 cf,	Atten= 0%, Lag= 0.0 min
Primary =	0.97 cfs @	12.02 hrs, Volume=	2,910 cf	

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Peak Elev= 309.49' @ 12.03 hrs
Flood Elev= 309.25'

Device	Routing	Invert	Outlet Devices
#1	Primary	306.75'	**12.0" Round Culvert** L= 105.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 306.75' / 306.25' S= 0.0048 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.79 sf

Primary OutFlow Max=0.84 cfs @ 12.02 hrs HW=309.47' TW=309.38' (Dynamic Tailwater)
1=Culvert (Outlet Controls 0.84 cfs @ 1.06 fps)

Summary for Pond CB3: CB3

[90] Warning: Qout>Qin may require smaller dt or Finer Routing
[87] Warning: Oscillations may require smaller dt or Finer Routing (severity=738)

Inflow Area =	2,125 sf,100.00% Impervious,	Inflow Depth = 6.26"	for 100-yr event
Inflow =	0.37 cfs @ 12.01 hrs, Volume=	1,109 cf	
Outflow =	0.40 cfs @ 12.01 hrs, Volume=	1,107 cf, Atten= 0%, Lag= 0.0 min	
Primary =	0.40 cfs @ 12.01 hrs, Volume=	1,107 cf	

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Peak Elev= 309.24' @ 12.02 hrs
Flood Elev= 309.60'

Device	Routing	Invert	Outlet Devices
#1	Primary	306.25'	**12.0" Round Culvert** L= 10.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 306.25' / 306.15' S= 0.0100 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 0.79 sf

Primary OutFlow Max=0.00 cfs @ 12.01 hrs HW=309.21' TW=309.23' (Dynamic Tailwater)
1=Culvert (Controls 0.00 cfs)

Summary for Pond DMH1: DMH1

[87] Warning: Oscillations may require smaller dt or Finer Routing (severity=75)
[80] Warning: Exceeded Pond CB1 by 0.87' @ 20.20 hrs (2.00 cfs 7,257 cf)
[80] Warning: Exceeded Pond CB2 by 0.88' @ 20.20 hrs (1.99 cfs 7,273 cf)

Inflow Area =	13,944 sf,100.00% Impervious,	Inflow Depth = 6.26"	for 100-yr event
Inflow =	2.40 cfs @ 12.01 hrs, Volume=	7,276 cf	
Outflow =	2.40 cfs @ 12.01 hrs, Volume=	7,276 cf, Atten= 0%, Lag= 0.0 min	
Primary =	2.40 cfs @ 12.01 hrs, Volume=	7,276 cf	

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs

Peak Elev= 309.39' @ 12.02 hrs
Flood Elev= 310.00'

Device	Routing	Invert	Outlet Devices
#1	Primary	306.25'	**15.0" Round Culvert** L= 16.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 306.25' / 306.15' S= 0.0063 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 1.23 sf

Primary OutFlow Max=2.18 cfs @ 12.01 hrs HW=309.36' TW=309.23' (Dynamic Tailwater)
↑—**1=Culvert** (Inlet Controls 2.18 cfs @ 1.78 fps)

Summary for Pond DMH2: DMH2

[80] Warning: Exceeded Pond CB3 by 2.60' @ 12.52 hrs (5.48 cfs 53,952 cf)
[80] Warning: Exceeded Pond DMH1 by 1.34' @ 20.19 hrs (4.66 cfs 28,304 cf)

Inflow Area = 16,069 sf,100.00% Impervious, Inflow Depth = 6.26" for 100-yr event
Inflow = 2.79 cfs @ 12.01 hrs, Volume= 8,383 cf
Outflow = 2.79 cfs @ 12.01 hrs, Volume= 8,383 cf, Atten= 0%, Lag= 0.0 min
Primary = 2.79 cfs @ 12.01 hrs, Volume= 8,383 cf

Routing by Dyn-Stor-Ind method, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs
Peak Elev= 309.23' @ 12.01 hrs
Flood Elev= 309.90'

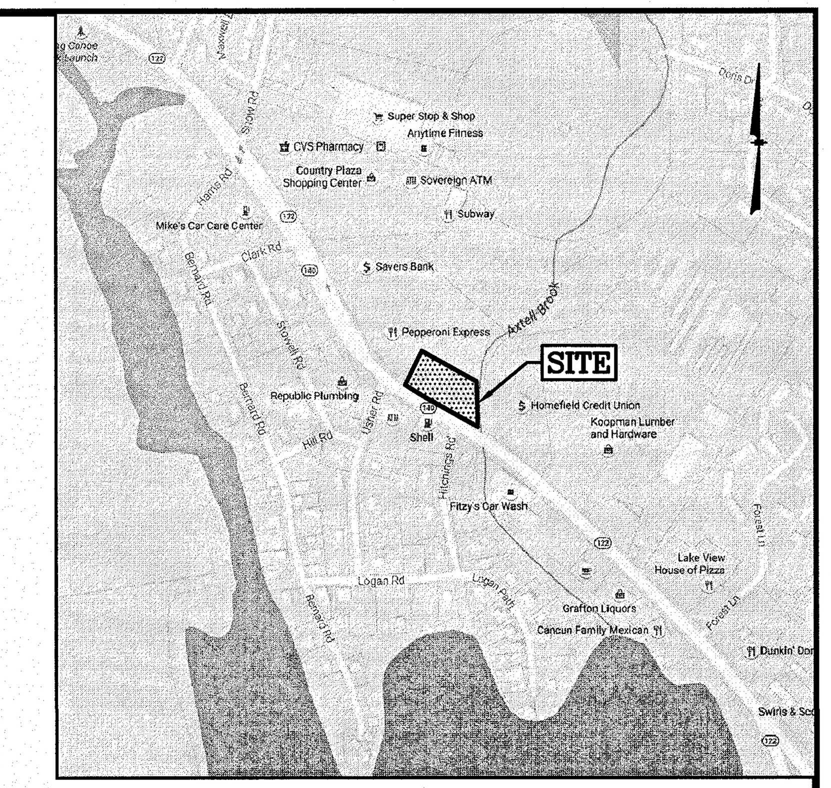
Device	Routing	Invert	Outlet Devices
#1	Primary	306.15'	**15.0" Round Culvert** L= 15.0' CPP, square edge headwall, Ke= 0.500 Inlet / Outlet Invert= 306.15' / 306.00' S= 0.0100 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 1.23 sf

Primary OutFlow Max=2.73 cfs @ 12.01 hrs HW=309.23' TW=309.01' (Dynamic Tailwater)
↑—**1=Culvert** (Inlet Controls 2.73 cfs @ 2.23 fps)

Summary for Link 1L: DESIGN POINT #1 (AXTELL BROOK)

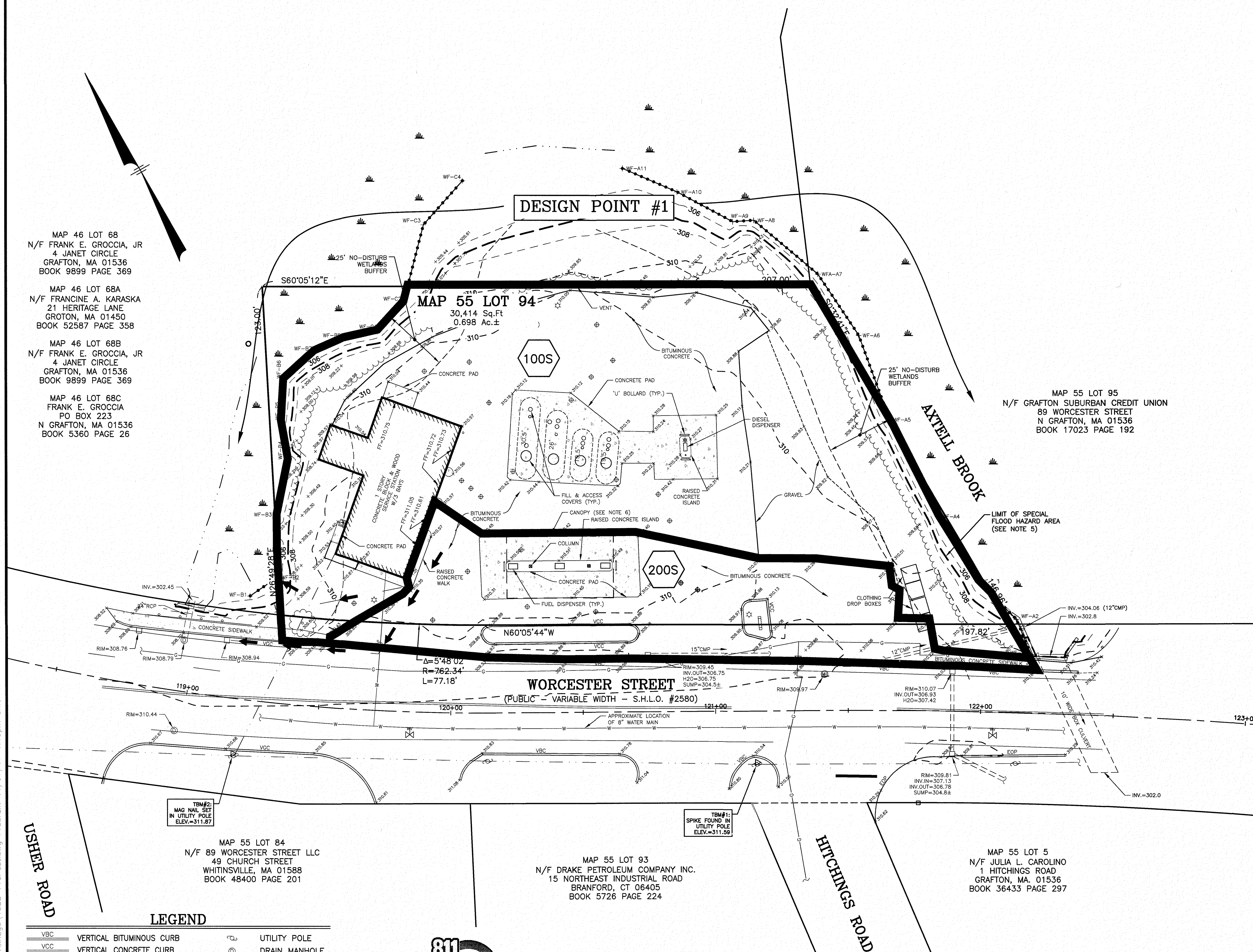
Inflow Area = 32,643 sf, 54.65% Impervious, Inflow Depth = 1.67" for 100-yr event
Inflow = 2.87 cfs @ 12.02 hrs, Volume= 4,553 cf
Primary = 2.87 cfs @ 12.02 hrs, Volume= 4,553 cf, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-30.00 hrs, dt= 0.01 hrs



LOCATION MAP

(NOT TO SCALE)



WATERSHED LEGEND:

SUBCATCHMENT: A relatively homogeneous area of land that drains into a single reach or pond. Each subcatchment generates a runoff hydrograph. (A subcatchment may also be used to account for the rain falling directly on the surface of a pond.)

REACH: A uniform stream, channel, or pipe that conveys water from one point to another reach or pond. The outflow of each reach is determined by a hydrograph routing calculation.

POND: A pond, swamp, dam, or other impoundment that fills with water from one or more sources and empties in a manner determined by a weir, culvert, or other device(s) at its outlet. The outflow(s) of each pond is determined by a hydrograph routing calculation. The primary and/or secondary outflow may drain into a reach or into another pond.

Time of Concentration Path (Tc)

GRAPHIC SCALE

(IN FEET)
1 inch = 20 ft.

LEGEND

VBC	VERTICAL BITUMINOUS CURB		UTILITY POLE
VCC	VERTICAL CONCRETE CURB		DRAIN MANHOLE
VGC	VERTICAL GRANITE CURB		SEWER MANHOLE
	OVERHEAD SERVICE WIRES		GAS METER
SSWL	SINGLE SOLID WHITE LINE		SPOT ELEVATION
W	WATER LINE		BOLLARD
G	GAS LINE		SIGN
	WETLAND LINE		OBSERVATION WELL
90	CONTOUR ELEVATION		TREE
	CHAIN LINK FENCE		

811 DigSafe MA-ME-NH-RI-VT

NO.	DESCRIPTION	BY	DATE
	REVISIONS		

PRE DEVELOPMENT DRAINAGE PLAN

ASSESSORS MAP 55 LOT 94
88 WORCESTER STREET
GRAFTON, MASSACHUSETTS
PREPARED FOR:
PETROGAS GROUP NEW ENGLAND, INC.
168 NORTH MAIN STREET
ANDOVER, MA 01810

MHF Design Consultants, Inc.
44 Stiles Road, Suite One
Salem, New Hampshire 03079
(603) 893-0720
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SCALE: 1"=20'	DATE: NOVEMBER 7, 2017		DRAWING NO. 4088PrePost.DWG
DRAWN BY:	CHECKED BY:	PROJECT NO.	SHEET NO.
CMT	DRJ	408816	1 OF 1

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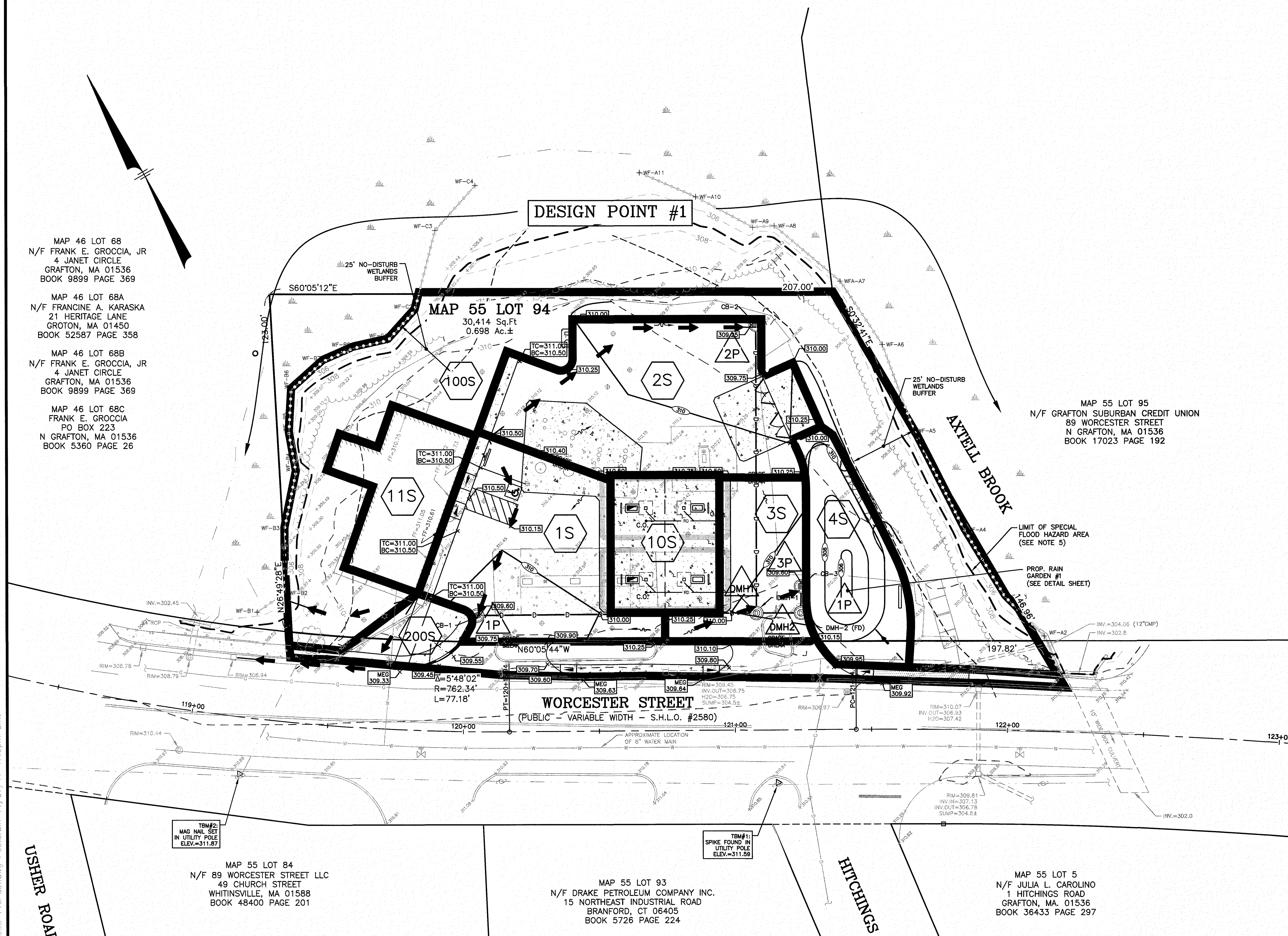

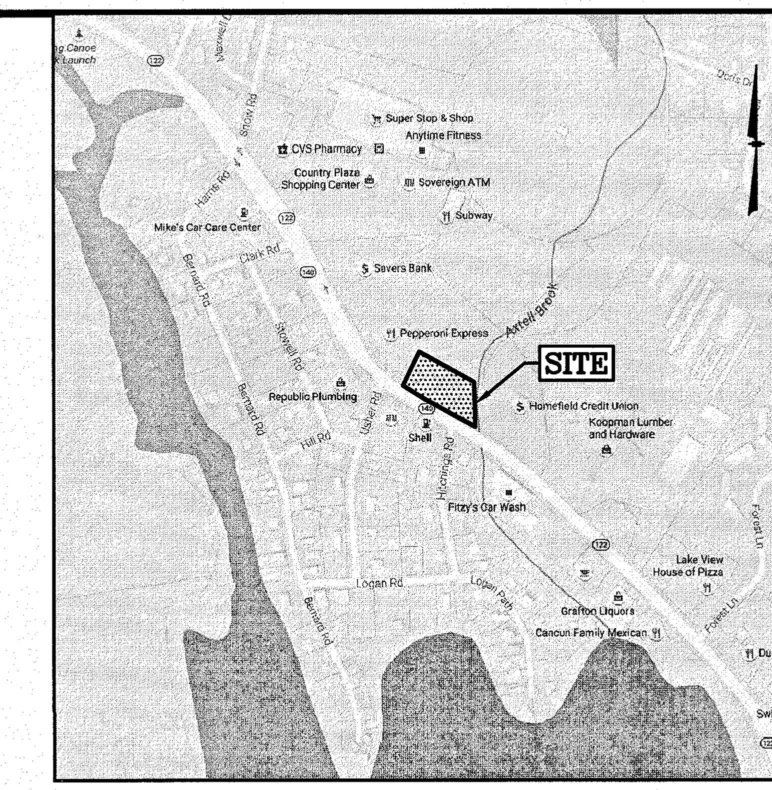

LOCATION MAP

(NOT TO SCALE)

WATERSHED LEGEND:

1 (hexagon) SUBCATCHMENT: A relatively homogeneous area of land that drains into a single reach or pond. Each subcatchment generates a runoff hydrograph. (A subcatchment may also be used to account for the rain falling directly on the surface of a pond.)

1 (square) REACH: A uniform stream, channel, or pipe that conveys water from one point to another reach or pond. The outflow of each reach is determined by a hydrograph routing calculation.

1 (triangle) POND: A pond, swamp, dam, or other impoundment that fills with water from one or more sources and empties in a manner determined by a weir, culvert, or other device(s) at its outlet. The outflow(s) of each pond is determined by a hydrograph routing calculation. The primary and/or secondary outflow may drain into a reach or into another pond.

Time of Concentration Path (Tc)

GRAPHIC SCALE

20 0 10 20 40 80

(IN FEET)
1 inch = 20 ft.

NO.	DESCRIPTION	BY	DATE
	REVISIONS		

POST DEVELOPMENT DRAINAGE PLAN

ASSESSORS MAP 55 LOT 94
88 WORCESTER STREET
GRAFTON, MASSACHUSETTS
PREPARED FOR:
PETROGAS GROUP NEW ENGLAND, INC.
168 NORTH MAIN STREET
ANDOVER, MA 01810

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SCALE: 1"=20'	DATE: NOVEMBER 7, 2017		DRAWING NO. 4088PrePost.DWG
DRAWN BY:	CHECKED BY:	PROJECT NO.	SHEET NO.
CMT	DRJ	408816	1 OF 1

LEGEND

VBC — VERTICAL BITUMINOUS CURB	UTILITY POLE
VCC — VERTICAL CONCRETE CURB	DRAIN MANHOLE
VGC — VERTICAL GRANITE CURB	SEWER MANHOLE
OVERHEAD SERVICE WIRES	GAS METER
SSWL — SINGLE SOLID WHITE LINE	SPOT ELEVATION
W — WATER LINE	BOLLARD
G — GAS LINE	SIGN
WETLAND LINE	OBSERVATION WELL
90 — CONTOUR ELEVATION	TREE
CHAIN LINK FENCE	

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OPERATION & MAINTENANCE PLAN
And
LONG TERM POLLUTION PREVENTION PLAN
For
STORMWATER MANAGEMENT SYSTEMS

Map 55 Lot 94

88 Worcester Street
Grafton, MA 01536

Prepared For:

Petrogas Group New England, Inc.
168 North Main Street
Andover, MA 01810

November 7, 2017

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MHF Project # 408816

OPERATION & MAINTENANCE PLAN AND LONG TERM POLLUTION PREVENTION PLAN

The Stormwater Policy developed by the Massachusetts Department of Environmental Protection and Office of Coastal Zone Management requires that an Operation and Maintenance Plan (O&M) and a Long Term Pollution Prevention Plan (LTPPP) be submitted for review and approval. As suggested in the Stormwater Handbook these plans have been combined to provide one focal point for the control of stormwater quality and quantity from the site. The plans shall include the parties responsible for scheduling inspections and maintenance, routine and non-routine maintenance tasks, nutrient source control procedures and provisions for appropriate access and maintenance easements surrounding controls and extending to the public right-of-way.

The owner of record shall be responsible for the installation, operation, and maintenance of all stormwater management systems after construction and for the implementation of the LTPPP. Logs of inspections and cleanings shall be maintained by the owner of record and annual BMP inspection forms shall be filed with the Town of Grafton, as required. Copies will need to be kept for the most recent three years and made available to the Stormwater Authority upon request. An annual summary (in log form) of the Inspection and Maintenance performed on site shall also be included as part of the submittal.

OPERATION AND MAINTENANCE PLAN

Documentation
A maintenance log shall be kept summarizing inspections, maintenance and any corrective actions taken. The log shall include the date on which each inspection or maintenance task was performed, a description of the inspection findings or maintenance completed, and the name of the inspector or maintenance personnel performing the task. If a maintenance task requires the clean out of any sediments or debris, the location where the sediment and debris was disposed after removal will be indicated. Disposal of the accumulated sediment and hydrocarbons must be in accordance with applicable local, state, and federal guidelines and regulations. The logs shall be made accessible to department staff and a copy provided to the department upon request.

Inspection and Maintenance Frequency and Corrective Measures
The following areas, facilities and measures will be inspected and the identified deficiencies will be corrected. Clean out must include the removal and legal disposal of any accumulated sediments and debris in accordance with applicable local, state, and federal guidelines and regulations.

1. Street Sweeping
Sweeping should be conducted a minimum of once per month (primarily during spring and fall). Sweeping shall be done once in the early fall and then immediately following spring snowmelt to remove sand and other debris. Pavement surfaces shall be swept at other times such as in the fall after leaves have dropped to remove accumulated debris. Since contaminants typically accumulate within 12 inches of the curbline, street cleaning operations should concentrate in cleaning curb and gutter lines for maximum pollutant removal efficiency. Other areas shall also be swept periodically when visual buildup of debris is apparent. Once removed from paved surfaces, the sweeping must

be handled and disposed of properly. In accordance with MassDEP's Bureau of Waste Prevention, the reuse and disposal of sweepings can be used in three ways: In one of the ways already approved by MassDEP (e.g. daily cover in a landfill, additive to compost, fill in a public way); if approved under a Beneficial Use Determination; disposed in a landfill.

2. Deep Sump Hooded Catch Basins

Inspect catch basins at least 4 times per year and at the end of the foliage and snow removal seasons (preferably in spring and fall) to ensure that the catch basins are working in their intended fashion and that they are free of debris. Sediment must also be removed 4 times per year of whenever the depth of deposits is greater than or equal to one half the depth form the bottom of the invert of the lowest pipe in the basin. If the basin outlet is designed with a hood to trap floatable materials check to ensure watertight seal is working. At a minimum, remove floating debris and hydrocarbons at the time of the inspection. Sediment and debris can be removed by a clamshell bucket; however a vacuum truck is preferred. A vacuum truck must be used at a minimum of once per year for sediment removal. Disposal of the accumulated sediment and hydrocarbons must be in accordance with applicable local, state, and federal guidelines and regulations.

3. Vegetated Areas

Inspect slopes and embankments early in the growing season to identify active or potential erosion problems. Replant bare areas or areas with sparse growth. Where rill erosion is evident, armor the area with an appropriate lining or divert the erosive flows to on-site areas able to withstand the concentrated flows.

4. Rain Garden Areas

The system should initially be inspected within the first three months after completion of the site's construction and after any rainfall event exceeding 2.5 inches in a 24 hour period. The system should be inspected at least twice annually thereafter.

Preventative maintenance will aid in proper function of the Rain Garden Areas. Inspect for trash and debris on a month to month basis year round. Additional mulch should be laid down on an annual basis, preferably in the springtime. Prune any plantings and remove dead vegetation on an annual basis in the spring or fall and any dead vegetation should be replanted in the springtime. At least annually, the system should be inspected for drawdown time. In the event the Rain Garden Areas needs to be replaced due to failure or other reasons, any vegetation & filter media should be replaced in either the late spring or early summer.

5. Hydrodynamic Separator (First Defense Units)

Initial maintenance to be performed twice a year for the first year after the unit is online and operational. A vacuum truck must be used at a minimum of once per year for sediment removal. Refer to the attached First Defense Maintenance Guide for operation and maintenance procedures and schedules thereafter.

6. Snow Storage and Removal

Proposed snow storage areas are as shown, on the Site Improvement Plans prepared for Petrogas Group New England, Inc., and any excess snow is to be trucked offsite. During the winter months all snow is to be stored such that snowmelt is controlled. In the event the amount of snow exceeds

such capacity, it is to be removed off-site. The minimum amount of deicing chemicals needed is to be used. Avoid disposing of snow on top of storm drain catch basins or in stormwater drainage swales or ditches.
For questions and additional information regarding snow storage or disposal, please contact the Mass DEP's Central Regional Office in Worcester at 508-792-7650.

LONG TERM POLLUTION PREVENTION PLAN

In accordance with DEP Stormwater Standard #4 the development and implementation of suitable practices for source control and pollution prevention shall be incorporated in a Long Term Pollution Prevention Plan (LTPPP). The primary focus of the LTPPP is to establish procedures and controls for limiting the potential sources of pollutants, including nutrients that may contribute to excessive contaminant levels in the site's stormwater runoff. To this end the following source controls and procedures will be in place at the site:

- **Good House Keeping –** It shall be the responsibility of the property owner to keep the site clean at all times. Refuse disposal and pickup shall occur on a regular basis and all material shall be disposed of in the specified dumpster location area on the Site Development Plans.
- **Storing Material and waste products inside or under cover** – No material storage is to take place outside the proposed facility on either paved or lawn areas. All material stored on site will conform with all storage requirements of local, state and federal agencies.
- **Routine inspections and maintenance of stormwater BMP's** – Refer to the Operation and Maintenance procedures for each BMP as described in the O&M Plan as described herein.
- **Spill prevention and response** – An Emergency Response Guideline will be provided for the development including an appropriately sized spill recovery kit and access to an emergency environmental cleanup vendor.
- **Maintenance of lawns, gardens and other landscaped areas** – All landscaping and maintenance to be performed by an authorized company chosen by the property owner.
- **Storage and use of fertilizers, herbicides and pesticides** – All landscape maintenance will be conducted by an authorized company chosen by the property owner. Any application of herbicides or pesticides will be applied by a licensed applicator.
- **Proper management of deicing chemicals and snow** – Deicing chemicals and snow removal shall primarily be the responsibility of the property owner additional information can be found in the O&M Plan as described herein.
- **Nutrient management plan**- The goal of the nutrient management plan is to minimize the potential sources of excess nutrients on the site and the release of nutrients in the stormwater from the site. This minimization relates both to infiltrated water and runoff. In general the nature of the site use will tend to reduce the nutrients in the stormwater. Further, procedures indicated above or in the O&M Plan related to deicing procedures, BMP maintenance procedures, and street sweeping will act to reduce the levels of nutrients in the stormwater, and the nutrients entering the adjacent wetland and the groundwater.

408816 Stormwater Operation and Maintenance Log

General Information			
Project Name			
NPDES Tracking No.		**Location**	
Date of Inspection		**Start/End Time**	
Inspector's Name(s)			
Inspector's Title(s)			
Inspector's Contact Information			
Describe present phase of construction			
Type of Inspection ☐ **Regular**		☐ **Post-storm event**	
Weather Information			
Current Conditions:			
Do you suspect that discharges may have occurred since the last inspection? ☐ Yes ☐ No			
Are there any discharges at the time of inspection? ☐ Yes ☐ No			

	Permanent (Post Construction) BMP Description	**BMP Installed and Operating Properly?**	**Corrective Action Needed**	**Party contacted / Method of contact**
1	Street Sweeping • Evidence of oil grease	☐ Yes ☐ No ☐ Yes ☐ No		
2	Deep Sump Hooded Catch Basin • Grates clear of debris • Inlet and outlet clear of debris • Evidence of oil grease • Observance of accumulated sediment • Evidence of structural deterioration • Evidence of spalling or cracking of structural parts • Evidence of flow bypassing facility	☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No		

3	First Defense Unit • Grates clear of debris • Inlet and outlet clear of debris • Observance of accumulated sediment • Evidence of oil grease • Evidence of flow bypassing facility	☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No		
4	Stone Lined Outlet Protection Area • Inlet/Inflow pipes clear of debris • Overflow spillway clear of debris • Outlet clear of debris • Evidence subsidence • Tree growth • Other (specify)	☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No		
5	Ditches, swales & channels • Inlet/Outlet clear of debris • Bottom surface clear of debris • Evidence of rilling or gullying • Observance of accumulated sediment • Bottom dewaters between storms • Vegetation healthy and growing • Standing water or wet spots • Tree growth • Other (specify)	☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No		
7	Aboveground Ponds/Basins • Basin bottom or trench surface clear of debris • Inlet/Inflow pipes clear of debris • Overflow spillway clear of debris • Outlet clear of debris	☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No		

	• Observance of accumulated sediment • Embankment erosion • Animal burrows • Unauthorized planting • Cracking, bulging, or sliding of embankments • Slope erosion • Other (specify) • Unauthorized planting • Cracking, bulging, or sliding of embankments • Slope erosion • Other (specify)	☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No		

Overall Site Issues

	BMP/activity	Implemented?	Maintained?	Corrective Action	Party contacted / Method of contact
1	Are all slopes and disturbed areas not actively being worked properly stabilized?	☐ Yes ☐ No	☐ Yes ☐ No		
2	Are natural resource areas (e.g., streams, wetlands, mature trees, etc.) protected with barriers or similar BMPs?	☐ Yes ☐ No	☐ Yes ☐ No		
3	Are perimeter controls and sediment barriers adequately installed (keyed into substrate) and maintained?	☐ Yes ☐ No	☐ Yes ☐ No		
4	Are discharge points and receiving waters free of sediment deposits?	☐ Yes ☐ No	☐ Yes ☐ No		
5	Are storm drain inlets properly protected?	☐ Yes ☐ No	☐ Yes ☐ No		
6	Is there evidence of sediment being tracked into the street?	☐ Yes ☐ No	☐ Yes ☐ No		
7	Is trash/litter from work areas collected and placed in covered dumpsters?	☐ Yes ☐ No	☐ Yes ☐ No		
8	Are washout facilities (e.g., paint, stucco, concrete) available, clearly marked, and maintained?	☐ Yes ☐ No	☐ Yes ☐ No		
9	Are vehicle and equipment fueling, cleaning, and maintenance areas free of spills, leaks, or any other deleterious material?	☐ Yes ☐ No	☐ Yes ☐ No		
10	Are materials that are potential stormwater contaminants stored inside or under cover?	☐ Yes ☐ No	☐ Yes ☐ No		
11	Are non-stormwater discharges (e.g., wash water, dewatering) properly controlled?	☐ Yes ☐ No	☐ Yes ☐ No		

ADDITIONAL COMMENTS

Attach Site Photos:

Certification statement:

"I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

Print name: ______________________________

Signature: ______________________ Date: ______________

Copies to:

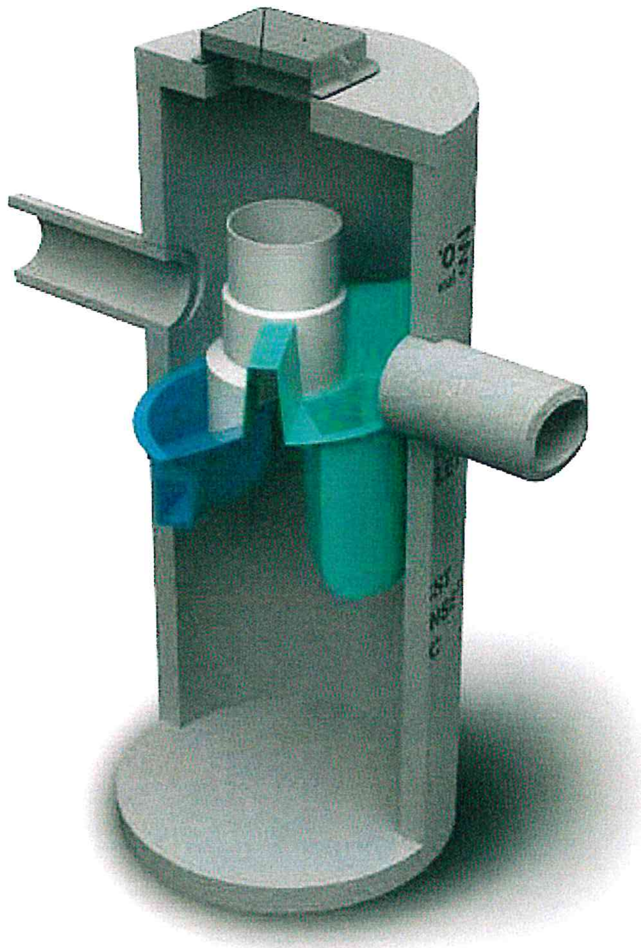
☐ Owner: ______________________________

☐ Contractor: ______________________________

☐ Conservation Commission: ______________________________

☐ MHF Project Manager: ______________________________

☐ Other: ______________________________



Operation and Maintenance Manual

First Defense® and First Defense®-HC

Vortex Separator for Stormwater Treatment

Stormwater Solutions

Turning Water Around ...®

Table of Contents

Hydro International (Stormwater), 94 Hutchins Drive, Portland ME 04102
Tel: (207) 756-6200 Fax: (207) 756-6212 Web: www.hydro-int.com

I. First Defense® by Hydro International

Introduction

The First Defense® is an enhanced vortex separator that combines an effective and economical stormwater treatment chamber with an integral peak flow bypass. It efficiently removes total suspended solids (TSS), trash and hydrocarbons from stormwater runoff without washing out previously captured pollutants. The First Defense® is available in several model configurations (refer to *Section II. Model Sizes & Configurations*, page 4) to accommodate a wide range of pipe sizes, peak flows and depth constraints.

Operation

The First Defense® operates on simple fluid hydraulics. It is self-activating, has no moving parts, no external power requirement and is fabricated with durable non-corrosive components. No manual procedures are required to operate the unit and maintenance is limited to monitoring accumulations of stored pollutants and periodic clean-outs. The First Defense® has been designed to allow for easy and safe access for inspection, monitoring and clean-out procedures. Neither entry into the unit nor removal of the internal components is necessary for maintenance, thus safety concerns related to confined-space-entry are avoided.

Pollutant Capture and Retention

The internal components of the First Defense® have been designed to optimize pollutant capture. Sediment is captured and retained in the base of the unit, while oil and floatables are stored on the water surface in the inner volume (Fig.1).

The pollutant storage volumes are isolated from the built-in bypass chamber to prevent washout during high-flow storm events. The sump of the First Defense® retains a standing water level between storm events. This ensures a quiescent flow regime at the onset of a storm, preventing resuspension and washout of pollutants captured during previous events.

Accessories such as oil absorbent pads are available for enhanced oil removal and storage. Due to the separation of the oil and floatable storage volume from the outlet, the potential for washout of stored pollutants between clean-outs is minimized.

Applications

- Stormwater treatment at the point of entry into the drainage line
- Sites constrained by space, topography or drainage profiles with limited slope and depth of cover
- Retrofit installations where stormwater treatment is placed on or tied into an existing storm drain line
- Pretreatment for filters, infiltration and storage

Advantages

- Inlet options include surface grate or multiple inlet pipes
- Integral high capacity bypass conveys large peak flows without the need for "offline" arrangements using separate junction manholes
- Proven to prevent pollutant washout at up to 500% of its treatment flow
- Long flow path through the device ensures a long residence time within the treatment chamber, enhancing pollutant settling
- Delivered to site pre-assembled and ready for installation

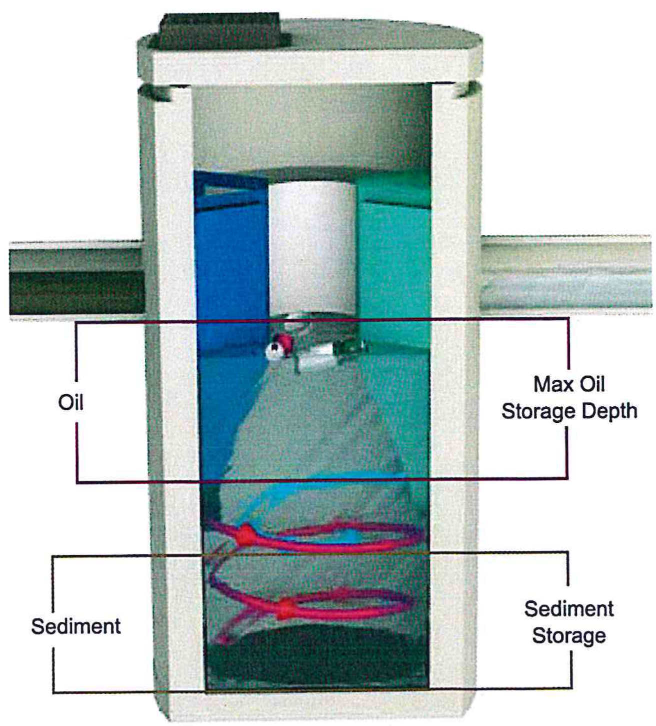


Fig.1 Pollutant storage volumes in the First Defense®.

II. Model Sizes & Configurations

The First Defense® inlet and internal bypass arrangements are available in several model sizes and configurations. The components of the First Defense®-4HC and First Defense®-6HC have modified geometries as to allow greater design flexibility needed to accommodate various site constraints.

All First Defense® models include the internal components that are designed to remove and retain total suspended solids (TSS), gross solids, floatable trash and hydrocarbons (Fig.2a - 2b). First Defense® model parameters and design criteria are shown in Table 1.

First Defense® Components

1. **Built-In Bypass**
2. **Inlet Pipe**
3. **Inlet Chute**
4. **Floatables Draw-off Port**
5. **Outlet Pipe**
6. **Floatables Storage**
7. **Sediment Storage**
8. **Inlet Grate or Cover**

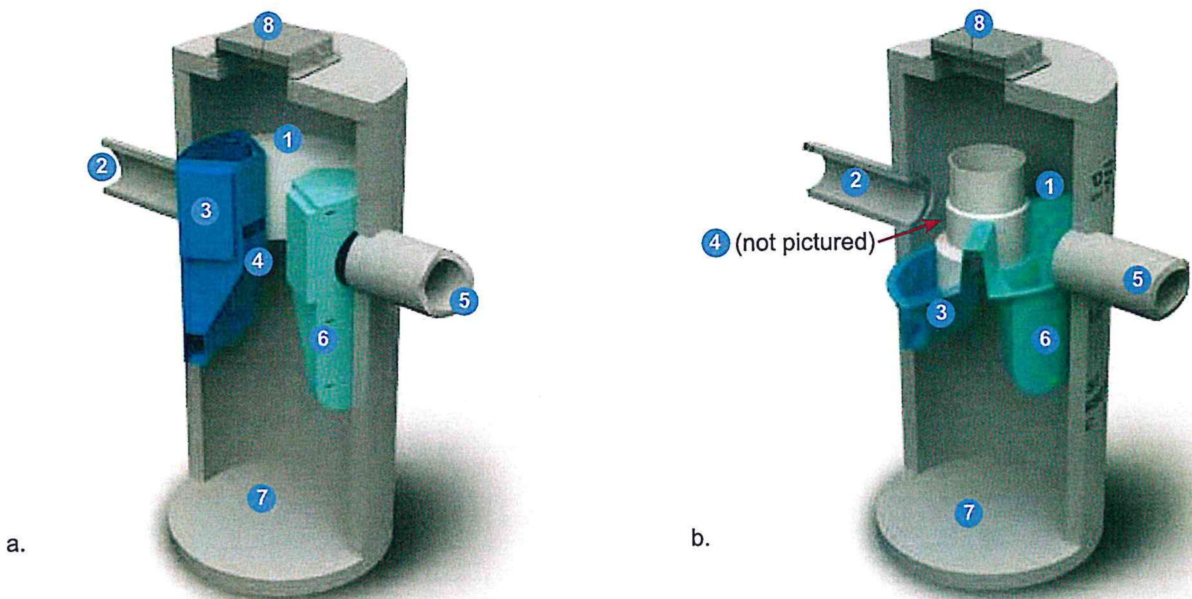


Fig.2a) First Defense®-4 and First Defense®-6; b) First Defense®-4HC and First Defense®-6HC, with higher capacity dual internal bypass and larger maximum pipe diameter.

Table 1. First Defense® Pollutant Storage Capacities and Maximum Clean out Depths

First Defense® Model Number	Diameter	Oil Storage Capacity	Oil Clean Out Depth	Maximum Sediment Storage Capacity[1]		Recommended Sediment Clean-out Capacity	
				Volume	Depth	Volume	Depth
	(ft / m)	(gal / L)	(in / cm)	(yd^3 / m^3)	(in / cm)	(yd^3 / m^3)	(in / cm)
FD-4	4 / 1.2	180 / 681	<23.5 / 60	1.3 / 1.0	33 / 84	0.7 / 0.5	18 / 46
FD-4HC		191 / 723	<24.4 / 62				
FD-6	6 / 1.8	420 / 1,590	<23.5 / 60	3.3 / 2.5	37.5 / 95	1.3 / 1.0	15 / 38
FD-6HC		496 / 1,878	<28.2 / 72				

NOTE

[1] Sediment storage capacity and clean out depth may vary, as larger sediment storage sump volumes are provided when required.

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III. Maintenance

Overview

The First Defense® protects the environment by removing a wide range of pollutants from stormwater runoff. Periodic removal of these captured pollutants is essential to the continuous, long-term functioning of the First Defense®. The First Defense® will capture and retain sediment and oil until the sediment and oil storage volumes are full to capacity. When sediment and oil storage capacities are reached, the First Defense® will no longer be able to store removed sediment and oil. Maximum pollutant storage capacities are provided in Table 1.

The First Defense® allows for easy and safe inspection, monitoring and clean-out procedures. A commercially or municipally owned sump-vac is used to remove captured sediment and floatables. Access ports are located in the top of the manhole.

Maintenance events may include Inspection, Oil & Floatables Removal, and Sediment Removal. Maintenance events do not require entry into the First Defense®, nor do they require the internal components of the First Defense® to be removed. In the case of inspection and floatables removal, a vactor truck is not required. However, a vactor truck is required if the maintenance event is to include oil removal and/or sediment removal.

Maintenance Equipment Considerations

The internal components of the First Defense®-HC have a centrally located circular shaft through which the sediment storage sump can be accessed with a sump vac hose. The open diameter of this access shaft is 15 inches in diameter (Fig.3). Therefore, the nozzle fitting of any vactor hose used for maintenance should be less than 15 inches in diameter.

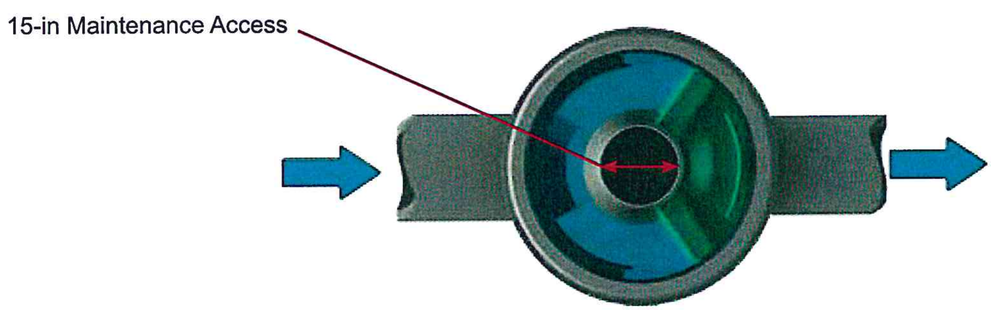

Fig.3 The central opening to the sump of the First Defense®-HC is 15 inches in diameter.

Determining Your Maintenance Schedule

The frequency of clean out is determined in the field after installation. During the first year of operation, the unit should be inspected every six months to determine the rate of sediment and floatables accumulation. A simple probe such as a Sludge-Judge® can be used to determine the level of accumulated solids stored in the sump. This information can be recorded in the maintenance log (see page 9) to establish a routine maintenance schedule.

The vactor procedure, including both sediment and oil / flotables removal, for a 6-ft First Defense® typically takes less than 30 minutes and removes a combined water/oil volume of about 765 gallons.

Inspection Procedures

1. Set up any necessary safety equipment around the access port or grate of the First Defense® as stipulated by local ordinances. Safety equipment should notify passing pedestrian and road traffic that work is being done.

2. Remove the grate or lid to the manhole.

3. Without entering the vessel, look down into the chamber to inspect the inside. Make note of any irregularities. Fig.4 shows the standing water level that should be observed.

4. Without entering the vessel, use the pole with the skimmer net to remove floatables and loose debris from the components and water surface.

5. Using a sediment probe such as a Sludge Judge®, measure the depth of sediment that has collected in the sump of the vessel.

6. On the Maintenance Log (see page 9), record the date, unit location, estimated volume of floatables and gross debris removed, and the depth of sediment measured. Also note any apparent irregularities such as damaged components or blockages.

7. Securely replace the grate or lid.

8. Take down safety equipment.

9. Notify Hydro International of any irregularities noted during inspection.

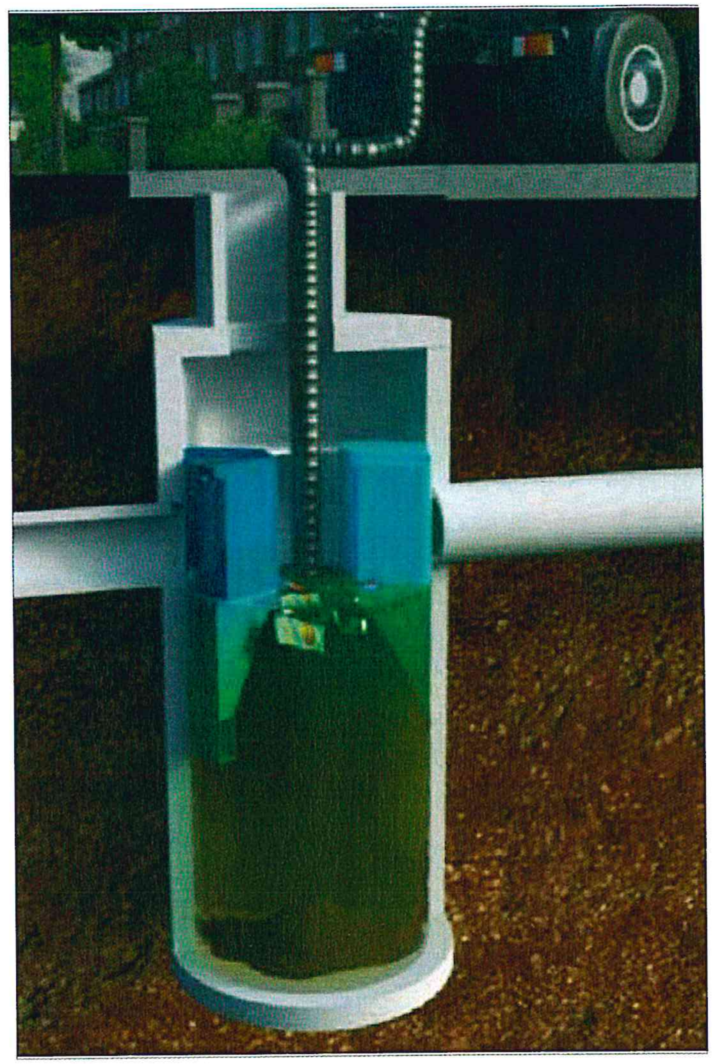

Fig.4 Floatables are removed with a vactor hose (First Defense model FD-4, shown).

Floatables and Sediment Clean Out

Floatables clean out is typically done in conjunction with sediment removal. A commercially or municipally owned sump-vac is used to remove captured sediment and floatables (Fig.5).

Floatables and loose debris can also be netted with a skimmer and pole. The access port located at the top of the manhole provides unobstructed access for a vactor hose and skimmer pole to be lowered to the base of the sump.

Scheduling

- Floatables and sump clean out are typically conducted once a year during any season.

- Floatables and sump clean out should occur as soon as possible following a spill in the contributing drainage area.

Recommended Equipment

- Safety Equipment (traffic cones, etc)
- Crow bar or other tool to remove grate or lid
- Pole with skimmer or net (if only floatables are being removed)
- Sediment probe (such as a Sludge Judge®)
- Vactor truck (flexible hose recommended)
- First Defense® Maintenance Log

Floatables and sediment Clean Out Procedures

1. Set up any necessary safety equipment around the access port or grate of the First Defense® as stipulated by local ordinances. Safety equipment should notify passing pedestrian and road traffic that work is being done.

2. Remove the grate or lid to the manhole.

3. Without entering the vessel, look down into the chamber to inspect the inside. Make note of any irregularities.

4. Remove oil and floatables stored on the surface of the water with the vactor hose (Fig.5) or with the skimmer or net (not pictured).

5. Using a sediment probe such as a Sludge Judge®, measure the depth of sediment that has collected in the sump of the vessel and record it in the Maintenance Log (page 9).

6. Once all floatables have been removed, drop the vactor hose to the base of the sump. Vactor out the sediment and gross debris off the sump floor (Fig.5).

7. Retract the vactor hose from the vessel.

8. On the Maintenance Log provided by Hydro International, record the date, unit location, estimated volume of floatables and gross debris removed, and the depth of sediment measured. Also note any apparent irregularities such as damaged components, blockages, or irregularly high or low water levels.

9. Securely replace the grate or lid.

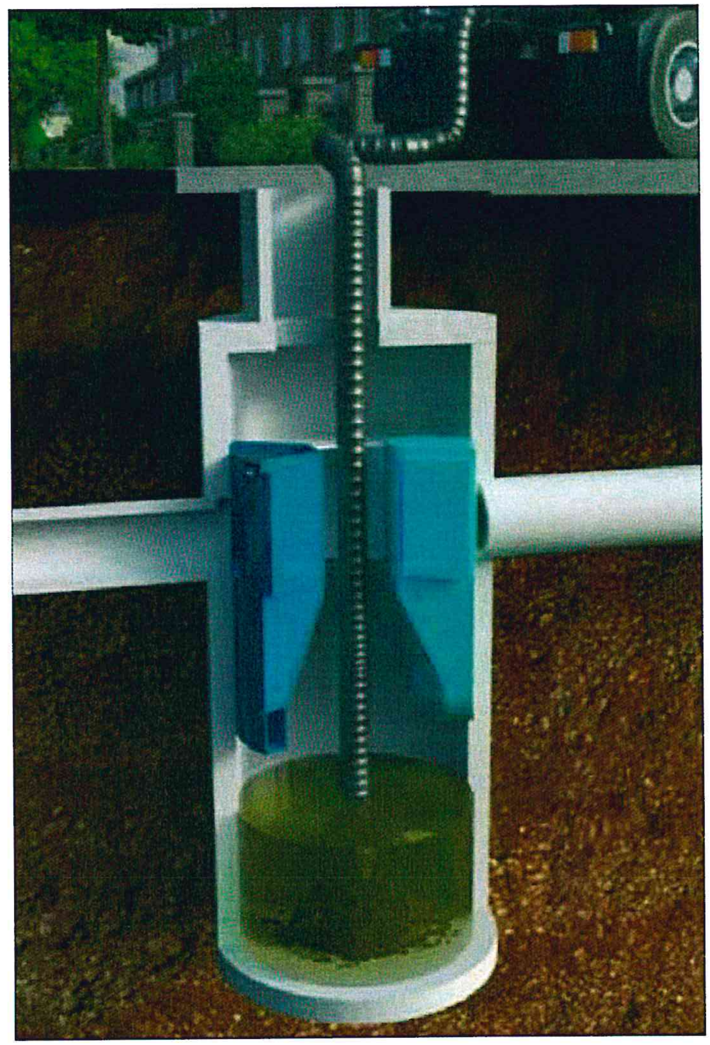

Fig.5 Sediment is removed with a vactor hose (First Defense model FD-4, shown).

Maintenance at a Glance

Activity	Frequency
Inspection	- Regularly during first year of installation - Every 6 months after the first year of installation
Oil and Floatables Removal	- Once per year, with sediment removal - Following a spill in the drainage area
Sediment Removal	- Once per year or as needed - Following a spill in the drainage area

NOTE: For most clean outs the entire volume of liquid does not need to be removed from the manhole. Only remove the first few inches of oils and floatables from the water surface to reduce the total volume of liquid removed during a clean out.

First Defense® Installation Log

HYDRO INTERNATIONAL REFERENCE NUMBER:	
SITE NAME:	
SITE LOCATION:	
OWNER:	CONTRACTOR:
CONTACT NAME:	CONTACT NAME:
COMPANY NAME:	COMPANY NAME:
ADDRESS:	ADDRESS:
TELEPHONE:	TELEPHONE:
FAX:	FAX:

INSTALLATION DATE: / /

MODEL SIZE (CIRCLE ONE): **FD-4** **FD-4HC** **FD-6** **FD-6HC**

INLET (CIRCLE ALL THAT APPLY): **GRATED INLET (CATCH BASIN)** **INLET PIPE (FLOW THROUGH)**

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Hydro International®

First Defense® Inspection and Maintenance Log

Date	Initials	Depth of Floatables and Oils	Sediment Depth Measured	Volume of Sediment Removed	Site Activity and Comments

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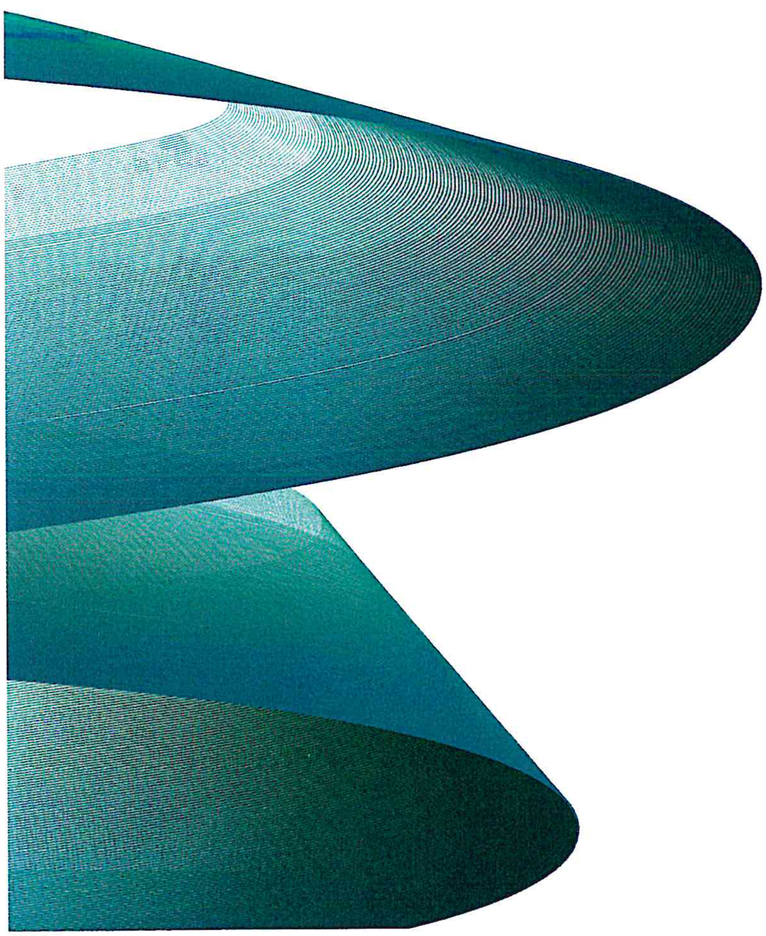
What is HX?

HX is Hydro Experience, it is the essence of Hydro. It's interwoven into every strand of Hydro's story, from our products to our people, our engineering pedigree to our approach to business and problem-solving.

HX is a stamp of quality and a mark of our commitment to optimum process performance. A Hydro solution is tried, tested and proven.

There is no equivalent to Hydro HX.



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